PB82-238668

Determination of Effects of Ambient Conditions on Aircraft Engine Emissions ALF 502 Combustor Rig Testing and Engine Verification Test

Avco Lycoming Engine Group
Stratford, CT

Prepared for

Environmental Protection Agency
Ann Arbor, MI

Jun 77

U.S. Department of Commerce
National Technical Information Service
NTIS

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-460/3/-77-017

2.

3. RECIPIENT'S ACCESSION NO. PB82-238668

4. TITLE AND SUBTITLE
Determination of the Effects of Ambient
Conditions on Aircraft Engine Emissions
ALF 502 Combustor Rig and Engine Verification Test

5. REPORT DATE June, 1977

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S) H. F. Trembley, Jr.

8. PERFORMING ORGANIZATION REPORT NO. Lyc 77-54

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Avco Lycoming Division
Stratford, Connecticut 06497

10. PROGRAM ELEMENT NO.

11. CONTRACT/GRANT NO. 68-03-2383

12. SPONSORING AGENCY NAME AND ADDRESS
U. S. Environmental Protection Agency
Office of Air and Water Management
Office of Mobile Source Air Pollution Control
Emission Control Tech. Div., Ann Arbor, MI 48105

13. TYPE OF REPORT AND PERIOD COVERED Final Mar 1976-Jan 1977

14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

A program was conducted by Avco Lycoming Engine Group under Contract No. 68-03-2383 with the Evironmental Protection Agency for the purpose of determining the effects of ambient temperature, humidity, and pressure on the emissions of hydrocarbons, carbon monoxide, oxides of nitrogen, and smoke. The approach involved the performance of two tasks. Task I was to gather data through Lycoming ALF 502 combustor rig testing under controlled simulated inlet conditions; Task II was to test a full-scale ALF 502 engine over a range of uncontrolled ambient conditions to verify the rig test data. These data will be part of a data base collected by the EPA for the development of correction factors for gas turbine engine emissions.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Aircraft Air Pollution Gas Turbines Emission Measurement Procedures Combustor Rig Testing		EPA 68A

18. DISTRIBUTION STATEMENT Release Unlimited

19. SECURITY CLASS *(This Report)* Unclassified

20. SECURITY CLASS *(This page)* Unclassified

21. NO. OF PAGES 260

22. PRICE

EPA Form 2220-1 (9-73)

PB82-238668

EPA-460/3-77-017
September 1977

DETERMINATION OF EFFECTS OF AMBIENT CONDITIONS ON AIRCRAFT ENGINE EMISSIONS

ALF 502 COMBUSTOR RIG TESTING AND ENGINE VERIFICATION TEST

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Mobile Source Air Pollution Control
Emission Control Technology Division
Ann Arbor, Michigan 48105

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA 22161

EPA-460/3-77-017

DETERMINATION OF EFFECTS OF AMBIENT CONDITIONS ON AIRCRAFT ENGINE EMISSIONS

ALF 502 COMBUSTOR RIG TESTING AND ENGINE VERIFICATION TEST

by

H.F. Trembley, Jr.

Avco Lycoming Division
550 South Main Street
Stratford, Connecticut 06497

Contract No. 68-03-2383

EPA Project Officer: Thomas Cackette

Prepared for

ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Mobile Source Air Pollution Control
Emission Control Technology Division
Ann Arbor, Michigan 48105

September 1977

i.a

This report is issued by the Environmental Protection Agency to report technical data of interest to a limited number of readers. Copies are available free of charge to Federal employees, current contractors and grantees, and nonprofit organizations - in limited quantities - from the Library Services Office (MD-35), Research Triangle Park, North Carolina 27711; or, for a fee, from the National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161.

This report was furnished to the Environmental Protection Agency by Avco Lycoming Division, 550 South Main Street, Stratford, Connecticut, in fulfillment of Contract No. 68-03-2383. The contents of this report are reproduced herein as received from Avco Lycoming Division. The opinions, findings, and conclusions expressed are those of the author and not necessarily those of the Environmental Protection Agency. Mention of company or product names is not to be considered as an endorsement by the Environmental Protection Agency.

Publication No. EPA-460/3-77-017

PREFACE

The investigation described herein was conducted by the Avco Lycoming Division, Stratford, Connecticut under EPA Contract Number 68-03-2383. The program period of performance was March 1976 through May 1977.

The objective of this program was to establish a data base from which the effects of ambient variations on gas turbine emissions can be evaluated.

The Avco Lycoming Project Officer was John Sherman. Harry Trembley was the Principal Investigator and was responsible for all combustor rig and engine verification testing. The EPA Project Officer was Tom Cackette. EPA Contracting Officer was Albert W. Ahlquist .

All processed data were transmitted for analysis to Paul Donovan and H. T. Adams of Calspan Technology Products.

Significant contributions made by Lycoming Engineering and Technical Staff are appreciated by the author.

TABLE OF CONTENTS

Page

PREFACE iii

LIST OF ILLUSTRATIONS ix

LIST OF TABLES xii

1.0 INTRODUCTION 1-1

2.0 SUMMARY 2-1

3.0 CONCLUSIONS 3-1

4.0 RECOMMENDATIONS 4-1

5.0 BACKGROUND AND APPROACH 5-1

- 5.1 Problem Statement 5-1
- 5.2 Program Approach 5-1

6.0 ENGINE DESCRIPTION 6-1

- 6.1 General 6-1
- 6.2 Combustion System 6-3
  - 6.2.1 Description 6-3
  - 6.2.2 Combustor 6-3
  - 6.2.3 Fuel Injection System 6-3
- 6.3 Fuel And Power Control System 6-4
  - 6.3.1 General 6-4
  - 6.3.2 Gas Producer and Power Control System 6-4
  - 6.3.3 Variable Inlet Guide Vane Control and Actuator 6-6
  - 6.3.4 Interstage Air-Bleed and Control 6-6
- 6.4 General Performance Specification and EPAP Values Data 6-6
  - 6.4.1 Performance Specifications 6-6
  - 6.4.2 1977 Emissions Standard Comparison 6-6

7.0 TEST - POINT SELECTION 7-1

- 7.1 Engine Test 7-1
- 7.2 Combustor Rig Test 7-2

Preceding page blank

TABLE OF CONTENTS (Cont'd)

Page

8.0 MEASUREMENT TECHNIQUES AND EQUIPMENT........ 8-1

- 8.1 General.. 8-1
- 8.2 Emission Measurements......................... 8-1
- 8.3 Engine Emission Sampling Probe................ 8-1
- 8.4 Combustor Rig Emission Sampling Probe......... 8-5
- 8.5 Gaseous Emission Measurement Data System - DS18 8-5
  - 8.5.1 Hydrocarbon Analyzer.................. 8-5
  - 8.5.2 Chemiluminescent NO/NO$_x$ Analyzer.................................. 8-11
  - 8.5.3 CO/CO$_2$ Non-dispersive Infrared Analyzer (NDIR) 8-12
  - 8.5.4 Sample Flow System Description 8-12
  - 8.5.5 Calibration Flow System Description 8-15
  - 8.5.6 System Temperature Control 8-15
  - 8.5.7 Detector Flow Variance Compensation ... 8-16
  - 8.5.8 Data Output 8-17
- 8.6 Portable Digital Data Acquisition System - DS8 ... 8-17
- 8.7 Portable Smoke Measurement Data System - DS16C 8-18
- 8.8 Emission Measurement Techniques 8-18
  - 8.8.1 Background and Compliance 8-18
  - 8.8.2 Calibration and Instrument Checks 8-20
  - 8.8.3 Daily Pretest Checks 8-23
    - 8.8.3.1 Instrument Operation Check and Adjustments 8-23
    - 8.8.3.2 Clean Line and Pressure Check 8-23
    - 8.8.3.3 NO$_x$ Efficiency Test 8-25
    - 8.8.3.4 Residence Time Check 8-25
- 8.9 Sensors and Probes for Aerothermodynamic Data.. 8-25
- 8.10 Multiple Input Digital Data Acquisition System - DS10 8-27
- 8.11 Engine Cell Data System-IBM 1800 8-28
- 8.12 Humidity Measurement 8-29

9.0 COMBUSTOR RIG TESTING 9-1

- 9.1 General 9-1
- 9.2 Combustor Test Rig 9-1
  - 9.2.1 Rig Description 9-1
  - 9.2.2 Rig Gas Sampling System 9-4

TABLE OF CONTENTS (Cont'd)

Page

9.3 Combustor Test Facilities 9-4

9.3.1 General 9-4
9.3.2 Air Supply 9-4
9.3.3 Rig Air Humidification System 9-5
9.3.4 Fuel System 9-5
9.3.5 Gas Sample Probe Cooling 9-5
9.3.6 Performance Data Acquisition Area 9-8

9.4 Combustor Test Procedures 9-8

9.4.1 Start-Up Procedure 9-8
9.4.2 Humidity Control Procedure 9-9
9.4.3 Fuel Temperature Control 9-9
9.4.4 Combustor Performance Data Acquisition 9-9
9.4.5 Emissions Data Acquisition 9-9

9.5 Combustor Rig Data Reduction 9-10
9.6 Combustor Data 9-11

10.0 ENGINE VERIFICATION TESTING 10-1

10.1 General 10-1
10.2 Test Facilities 10-1
10.3 Engine Gas Sampling System 10-4
10.4 Engine Test Procedures 10-4

10.4.1 Pre-Engine Test Checks 10-4
10.4.2 Acquisition Sequence 10-4
10.4.3 Stabilization 10-4
10.4.4 Engine Performance Data Acquisition 10-4
10.4.5 Emission Data Acquisition 10-7

10.5 Engine Data Reduction 10-7
10.6 Engine Data 10-8

11.0 DISCUSSION 11-1

11.1 General 11-1
11.2 Fuel-Air Ratio Correlation 11-1
11.3 Humidity Correlation 11-2
11.4 Engine/Test Rig Emissions Equivalence 11-3

11.4.1 General 11-3
11.4.2 Performance Parameters (Independent Variables) 11-3
11.4.3 Emission Parameters (Dependent Variables) 11-5

TABLE OF CONTENTS (Cont'd)

Page

11.5 Data Plots 11-8

APPENDIXES A, B, and C

LIST OF ILLUSTRATIONS

Figure		Page
2-1	Engine Data Format	2-4
2-2	Combustor Data Format	2-5
6-1	Turbofan Engine (Typical)	6-1
6-2	Engine Modules	6-2
6-3	Power Control and Fuel System Schematic	6-5
7-1	ALF 502 Corrected Measured Gas Temperature Versus Referred Net Thrust	7-3
8-1	Engine Exhaust Averaging Gas Sample Probe	8-2
8-2	Engine Gas Sample Probe Drawing - Lycoming P/N TE 26808	8-3
8-3	Combustor Rig Gas Sample Probe Assembly	8-6
8-4	Combustor Rig Gas Sample Probe - TE 28010-01	8-7
8-5	Individual Gas Sample Probe - Rig Style Print - TE 28010-01	8-9
8-6	DS18 Emission Measurement Flow Schematic	8-13
8-7	DS16C Portable Smoke Measurement System Schematic	8-19
8-8	Residence Time Check Schematic	8-26
8-9	Dew Point Meter Operational Schematic	8-30
9-1	ALF 502 Combustor Test Rig Installation	9-2
9-2	Combustor Rig Assembly - Partial	9-3
9-3	Water Spray Installation	9-6
9-4	Water Spray Nozzle	9-7
10-1	Test Cell 13 Schematic	10-2
10-2	ALF 502 Engine Mounting	10-3
10-3	ALF 502 Gas Sample Probe Installation	10-5
10-4	Engine Performance Data Listing - Sample	10-6

Figure Page

11-1 Comparison of Calculated Emission Indexes Between Rig and Engine Tests 11-6

11-2 CO Emission Index Versus HC Emission Index Rig Test - Idle 11-9

11-3 CO Emission Index Versus HC Emission Index, Rig Test - 1.5 x Idle 11-10

11-4 CO Emission Index Versus HC Emission Index, Rig Test - Approach 11-11

11-5 CO Emission Index Versus T_{t3} Rig Test, Idle 11-12

11-6 CO Emission Index Versus T_{t3} Rig Test, 1.5 x Idle........ 11-13

11-7 CO Emission Index Versus T_{t3} Rig Test, Approach........ 11-14

11-8 HC Emission Index Versus T_{t3} Rig Test, Idle 11-15

11-9 HC Emission Index Versus T_{t3} Rig Test, 1.5x Idle......... 11-16

11-10 HC Emission Index Versus T_{t3} Rig Test, Approach........ 11-17

11-11 HC Emission Index Versus Fuel-Air Ratio, Rig Test - Idle 11-18

11-12 HC Emission Index Versus Fuel-Air Ratio, Rig Test - 1.5 x Idle 11-19

11-13 HC Emission Index Versus Fuel-Air Ratio, Rig Test - Approach 11-20

11-14 CO Emission Index Versus Fuel-Air Ratio, Rig Test - Idle 11-21

11-15 CO Emission Index Versus Fuel-Air Ratio, Rig Test - 1.5 x Idle 11-22

11-16 CO Emission Index Versus Fuel-Air Ratio, Rig Test - Approach 11-23

11-17 NO_x Emission Index Versus Fuel-Air Ratio, Rig Test - Idle 11-24

11-18 NO_x Emission Index Versus Fuel-Air Ratio, Rig Test - 1.5 x Idle 11-25

11-19 NO_x Emission Index Versus Fuel-Air Ratio, Rig Test - Approach 11-26

Figure Page

11-20 NO_x Emission Index Versus T_{t3}, Rig Test - Idle 11-27

11-21 NO_x Emission Index Versus T_{t3} Rig Test - 1.5 x Idle 11-28

11-22 NO_x Emission Index Versus T_{t3} Rig Test - Approach 11-29

11-23 CO Emission Index Versus HC Emission Index, Engine Test 11-30

11-24 HC Emission Index Versus Fuel-Air Ratio, Engine Test 11-31

11-25 CO Emission Index Versus Fuel-Air Ratio, Engine Test 11-32

11-26 NO_x Emission Index Versus Fuel-Air Ratio, Engine Test 11-33

11-27 NO_x Emission Index Versus T_{t3}, Engine Test 11-34

11-28 HC Emission Index Versus Referred Thrust, Engine Test 11-35

11-29 CO Emission Index Versus Referred Thrust, Engine Test 11-36

11-30 NO_x Emission Index Versus Referred Thrust, Engine 11-37

11-31 Smoke Number Versus Referred Thrust, Engine Test 11-38

LIST OF TABLES

Table		Page
2-1	ALF 502 Engine Power Settings	2-1
2-2	ALF 502 Engine Test Ambient Conditions	2-2
2-3	ALF 502 Combustor Simulated Ambient Conditions	2-3
6-1	Guaranteed Performance at Sea Level Static Standard Day Atmospheric Conditions	6-7
6-2	Engine EPAP Calculation and Comparison to EPA 1977 Requirements.	6-8
7-1	Referral Parameters	7-4
7-2	Combustor Rig Test Conditions	7-5
8-1	Hydrocarbon Analyzer Pressure Correction Factors	8-21
8-2	NO/NO$_x$ Analyzer Pressure Correction Factors	8-22
8-3	1976 Diesel Cross Reference Service	8-24
11-1	Comparison of Engine and Rig Testing	11-4

1.0 INTRODUCTION

The effort described in this report and the resulting data obtained were performed at the Avco Lycoming facility in Stratford, Connecticut, for the Environmental Protection Agency, Emissions Control Technology Division, Ann Arbor, Michigan under Contract No. 68-03-2383.

The Lycoming combustor facilities were used to generate emissions data of hydrocarbons, carbon monoxide, oxides of nitrogen, and smoke from an ALF 502 combustor rig test under controlled atmospheric conditions. The measured emissions reflected the variations due to humidity, ambient temperature, and barometric pressures which could then be applied to the actual engine operation and measurements.

An engine verification emission test was also conducted on the ALF 502 turbofan engine over a range of uncontrolled ambient conditions to confirm combustor rig results.

The resulting data from the program were submitted to the EPA for the purpose of developing correction factors for engine emissions data. The correction factors are to provide the means of standardizing engine emission data acquired under uncontrolled conditions to show compliance to the 1979 EPA Aircraft and Aircraft Engine Emission Standard.

2.0 SUMMARY

Seven test series were conducted to measure exhaust emissions on an Avco Lycoming ALF 502 turbofan engine covering a range of ambient conditions of temperature, barometric pressure, and humidity. Each test series included the seven engine power levels listed in Table 2-1; and the ambient conditions encountered are indicated in Table 2-2.

Using the same model combustor hardware (liner, fuel manifold, housing, and flow divider), three combustor rig emission test series were performed at idle, 1.5 times idle, and approach conditions. Each test series covered the wide range of controlled ambient conditions listed in Table 2-3. The corresponding combustor conditions can be found in Table 7-2.

The engine and rig emissions data including hydrocarbon, carbon monoxide, carbon dioxide, oxides of nitrogen and smoke were recorded, processed, and checked for validity and forwarded to the EPA and Calspan Technology Products for analysis and development of correction factors. Calspan Technology Products was the company chosen by the EPA to process the data obtained under this program and correlate and combine these results with similar data obtained from other engine manufacturers. The formats used for both engine and rig test data transmittal are shown in Figures 2-1 and 2-2.

TABLE 2-1. Engine Power Settings

Mode	Thrust
Taxi Idle	400 lb
1.5 x Taxi Idle	600 lb
Approach	30% of T.O.
Cruise No. 1	44.6% of T.O.
Cruise No. 2	52.3% of T.O.
Climbout	90% of T.O.
Takeoff	100% of T.O.
Standard Day Takeoff (T.O.) Power = 6500 lb	

TABLE 2-2. ALF 502 ENGINE TEST AMBIENT CONDITIONS

Test No.	Ambient* Pressure (psia)	Average Ambient Temperature (°F)	Humidity Grains of H_2O (lb Air)
22	14.80	76.6	101.
23	14.80	70.9	114
24	14.71	76.	107.
25	14.62	77.6	124.
26	14.63	73.3	121.
27	14.68	78.5	111.
28	14.71	63.5	62.
Maximum	14.80	18.5	124
Minmum	14.62	63.5	62
Range	0.18	15.0	62

NOTES: Tabulated pressures are at engine idle condition. For engine inlet pressure at higher powers, including cell depression, see Appendix C, Engine Data.

TABLE 2-3. ALF 502 COMBUSTOR SIMULATED AMBIENT CONDITIONS

Test Point	Temperature		Humidity		Pressure	
	°C	°F	Grams H_2O/Kg Air	Grains H_2O/ lb Air	KP_a	H_g
1	-7	19	3.6	25	101.3	29.92
2	4	39	│	│	│	│
3	15	59	│	│	│	│
4	29.5	85	│	│	│	│
5	40.5	105	│	│	│	│
6	4	39	5	35	│	│
7	15	59	7.5	52.5	│	│
8	29.5	85	7.5	52.5	│	│
9	40.5	105	7.5	52.5	│	│
10	15	59	10	70	│	│
11	29.5	85	15	105	│	│
12	40.5	105	15	105	│	│
13	29.5	85	25	175	│	│
14	40.5	105	25	175	↓	↓
15	-7	19	3.6	25	109.32	32.28
16	15	59	7.5	52.5	│	│
17	40.5	105	3.6	25	│	│
18	40.5	105	25	175	↓	↓
19	-7	19	3.6	25	88	25.98
20	15	59	7.5	52.5	│	│
21	40.5	105	3.6	25	│	│
22	40.5	105	25	175	↓	↓

ENGINE DATA FORMAT

```
ENGINE TEST DATA                                                                   051375
DATE                           DATA POINT              TEST CELL                   051375
5/12/75                        051375                  13                          051375
INSTRUMENT OPERATOR                                    TEST OPERATOR               051375
TREMBLEY                                               WALSH                       051375
ENGINE MANUFACTURER            MODEL                   SERIAL NUMBER               051375
LYCOMING                       ALF-502                 LF04                        051375
FUEL IDENT.                    FUEL FLOW PPH           MANIFOLD FUEL TEMP FAH      051375
JET-A HC RATIO 0.167           2000.                   125.                        051375
BELLMOUTH AIR FLOW LB/SEC      CORE AIRFLOW LB/SEC     FUEL-AIR RATIO MEAS.        051375
270.                           25.                     .0156                       051375
PT3 PSIA                       TT3 DEG. RANKINE                                    051375
80.                            713.                                                051375
PT9 PSIA                       TT9 DEG RANKINE         EPR                         051375
15.5                           1200.                   8.0                         051375
NET THRUST LBS                 N1 RPM                  N2 RPM                      051375
6500.                          18000.                  7000.                       051375
ACTUAL INLET PRESSURE PO PSIA                                                      051375
14.7                                                                               051375
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                                           051375
519.                                                                               051375
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                                051375
25.0                                                                               051375
FILTER AREA .372 SI                                                                051375
CLEAN CK SMOKE NUMBER 1                                                            051375
SMOKE NUMBER        VOL.-LITERS      FLOW-CFM PRESS.-PSIG   TEMP. DEG.FAH          051375
          35.                3.            .5        3.0              230.         051375
          44.                4.            .5        3.0              230.         051375
          54.                7.            .5        3.0              230.         051375
          64.               11.            .5        3.0              230.         051375
GASEOUS EMISSIONS                                                                  051375
                    FID         NDIR        NDIR        CHEMI       CHEMI          051375
                    UHC          CO          CO2         NO          NOX           051375
RANGE                1           3           3           2           2             051375
INSTR GAS TEMP      150.        55.         55.         55.         55.            051375
RAW VALUE MV        225.        400.        400.        750.        755.           051375
GAS CONCEN PPM(C)   179.5       534.        30567.      76.         80.            051375
GAS CONCEN PCT      0.0180      .0534       3.0567      .0076       .0080          051375
EMISSION INDEX      5.74        34.3        3077.       7.9         8.1            051375
FUEL-AIR RATIO      .0156                                                          051375
```

Figure 2-1. Engine Data Format.

COMBUSTOR RIG DATA FORMAT

```
COMBUSTOR RIG TEST                                                     051375
DATE                            DATA POINT         TEST CELL           051375
5/13/75                         051375             1                   051375
INSTRUMENT OPERATOR                                TEST OPERATOR       051375
TREMBLEY                                           WALSH               051375
ENGINE MANUFACTURER             MODEL              SERIAL NUMBER       051375
LYCOMING                        ALF-502            LF04                051375
FUEL IDENT.                     FUEL FLOW PPH      MANIFOLD FUEL TEMP FAH 051375
JET-A HC RATIO 0.167            2000.              125.                051375
ORIFICE AIRFLOW LB/SEC          PT3 PSIA           TT3 DEG.RANKINE     051375
25.                             100.               713.                051375
SIMULATED THRUST LBS            FUEL-AIR RATIO MEAS.                   051375
6500.                           .0156                                  051375
SIMULATED INLET PRESSURE PO PSIA                                       051375
14.7                                                                   051375
SIMULATED INLET TEMPERATURE TO DEG.RANKINE                             051375
519.                                                                   051375
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                    051375
25.0                                                                   051375
FILTER AREA .372 SI                                                    051375
CLEAN CK SMOKE NUMBER 1                                                051375
SMOKE NUMBER        VOL.-LITERS    FLOW-CFM PRESS.-PSIG  TEMP. DEC.FAH 051375
         35.                 3.         .5         3.0           230.  051375
         44.                 4.         .5         3.0           230.  051375
         54.                 7.         .5         3.0           230.  051375
         64.                11.         .5         3.0           230.  051375
GASEOUS EMISSIONS                                                      051375
                  FID        NDIR       NDIR       CHEMI      CHEMI    051375
                  UHC        CO         CO2        NO         NOX      051375
RANGE              1          3          3          2          2       051375
INSTR GAS TEMP    150.       55.        55.        55.        55.      051375
RAW VALUE MV      225.       400.       400.       750.       755.     051375
GAS CONCEN PPM(C) 179.5      534.       30567.     76.        80.      051375
GAS CONCEN PCT    0.0180     .0534      3.0567     .0076      .0080    051375
EMISSION INDEX    5.74       34.3       3077.      7.9        8.1      051375
FUEL-AIR RATIO    .0156                                                051375
```

Figure 2-2. Combustor Data Format.

3.0 CONCLUSIONS

Combustor rig testing provides a successful method of simulating a wide variety of ambient inlet conditions to determine their effects on engine emissions. The accurate control possible over pressure, temperature, humidity, fuel and air flows allows accurate assessment of the resulting variations in emissions. (Para 11-4)

Correlation between engine and rig data is acceptable when combustor conditions are closely duplicated in both tests, as evidenced by the approach power setting. (Para 11-4)

Extrapolating the results of the engine performance computer deck to yield idle and 1.5 idle operating conditions resulted in rig test fuel-air ratios that did not correlate with the engine test. The rig idle fuel-air mixture is richer and the rig 1.5 idle is leaner than occured during the engine test. This resulted in a lack of good correlation with the engine data at these power settings but has no effect between the relationship of emission index to ambient condition variations. (Para 11-4.2)

The data obtained from this test program provide a satisfactory data matrix for developing correlating factors in the lower power settings. (Para 11-4)

The humidification and measurement system developed for this program provides a reliable method of humidity control for combustor rig tests. (Para 11-3)

The design techniques used for sizing and mounting of the gas sample probes in both the engine and rig test provided representative samples of the exhaust emissions, as demonstrated by the measured versus emission-based fuel-air ratio correlations (Para 11-2).

4.0 RECOMMENDATIONS

Consolidate the data obtained by Lycoming in this program with other existing data to obtain correction factors for ambient conditions. (Para 5.1)

Incorporate the factors developed into the EPA regulations to allow emission tests to be accomplished at other than standard day ambient conditions. The incorporation of these correction factors should be preceded by an industry-wide review to assure successful application. (Para 5.1)

Modify EPA regulations describing test techniques to increase the minimum time between sample line contamination checks to provide an economical procedure. (Para 8.8.3)

5.0 BACKGROUND AND APPROACH

5.1 PROBLEM STATEMENT

The variability of emissions levels from a gas turbine engine is of significant importance to both the engine manufacturer in meeting air quality standards and the EPA for setting these standards. Although many variables can effect the pollutants of an engine, ambient condition variations directly affect the engine operating parameters and, therefore, the emission levels.

The EPA regulations specify engine power setting for which the data is to be taken. The test power is that power setting, which when corrected to standard day condition, corresponds to a specified percentage of rated power. Without satisfactory correction factors, engines can be tested for compliance to emission limits only on natural or controlled standard days.

The EPA, in recognizing these present deficiencies, is requesting data on different classes of engines operated at various ambient conditions and proposing to develop correction routines that would standardize the emission values. The test discussed herein is intended to contribute to a comprehensive data bank and the development of these correction factors by supplying the EPA with data from a class T_1 engine.

5.2 PROGRAM APPROACH

An ALF 502 combustor was tested in the component test facilities at Avco Lycoming at various controlled inlet conditions and engine level confirmation tests were run on a full turbofan configuration.

The required emissions data were obtained by using two of Lycoming's modern data systems; one is specifically engineered for accurate measurement of gaseous emissions from engines and combustor rigs, and the second for measurement of particulate emissions (smoke). Both combustor rig tests and full engine verification tests on the ALF 502 fan engine were run over a number of equivalent ambient and power conditions to provide a data matrix from which correlation factors may be obtained.

Sampling of the exhaust constituents for the rig and engine test was accomplished by a probe-averaging technique. The combustor rig gas sampling probe comprised an eight-leg, five-hole per leg (40 total) arrangement for a representative average of the circumferential and radial distributions typical at the combustor exit plane. The engine probe was of the standard cruciform averaging configuration with three holes per leg (12 total) sized and radially spaced as in the rig probe. This arrangement is sufficient for representative samples in the engine exhaust because of the mixing effect of the turbine section. This has been confirmed by the close correlation between calculated and measured fuel-air ratios in this program and previous testing.

The exhaust constituents measured were CO, CO_2, NO, NO_x, and unburned hydrocarbons (UHC). These emissions were measured using Lycoming's DS 18 data system. This system designed and built to meet the EPA system requirements incorporates the latest equipment and operation techniques.

All measurements using this system were made using the techniques described in Part 87, Title 40, published in the Federal Register, Volume 38, No. 136, July 1973, with exceptions notes in Appendix A.

The smoke system, DS16C, was used in conjunction with the DS18 gas analysis system to sample the particulate content of the combustor rig and engine exhaust.

The sample to the smoke system was obtained from the same probes and extracted upstream of the DS18 system by means of a selector valve. The smoke system then operates independently and obtains samples at the required flow rates. All procedures are in accordance with paragraph 87.85 of the Federal Register, Part 87.

The combustor and engine operating conditions were selected to meet the seven equivalent power points stated in the RFQ, i.e., (taxi) idle, 1.5 times idle power, climbout, approach, takeoff, and cruise. Idle power and cruise conditions were selected based on a typical airframe installation and power turbine configuration, while takeoff, climbout, and approach points were based on maximum engine turbine inlet temperature and powers as stated in the model specifications.

The combustor test rig was to have been operated at the seven simulated engine power conditions for each of the environmental conditions specified in Table 2-2. However, difficulties in achieving the higher power conditions limited the rig program to the three lower power settings: idle, 1.5 times idle, and approach.

6.0 ENGINE DESCRIPTION

6.1 GENERAL

The ALF 502 is a 6500 lb thrust twin-spool turbofan engine (Figure 6-1) with a 6:1 bypass ratio selected for improved cruise and loiter fuel consumption, as well as increased single-engine takeoff capability. The core engine derives from the Lycoming T55 series engine which has over three million hours of service experience. Accessories, including a completely self-contained oil system, are externally mounted on the fan module for maintainability, cool environment, and reduction of fire hazard.

The engine weighs 564 Kg (1245 lb) and has a basic diameter of 1.077 meters (42.4 inches) and overall length of 1.56 meters (61.43 inches), including spinner.

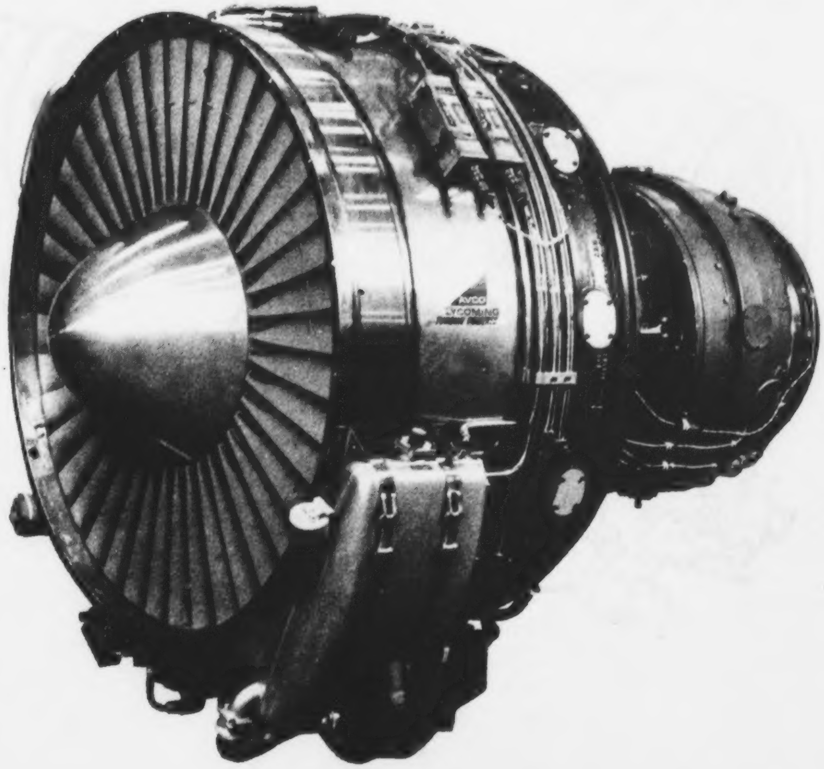


Figure 6-1. Turbofan Engine (Typical)

The low-pressure spool incorporates a single-stage fan that provides both the bypass efflux and airflow to the power producer. The air directed to the core engine is further compressed in the low-pressure spool by a single-stage supercharger. The low-pressure rotor is driven by a two-stage uncooled turbine through a single planetary reduction gear within the fan module. The high-pressure components of the engine include an axial/centrifugal compressor, a folded annular atomizing combustor, and a two-stage turbine to drive the compressor. The four basic modules are shown in Figure 6-2.

The two components that have a major effect on the engine's emissions profile, the combustor and fuel control, are described in this section.

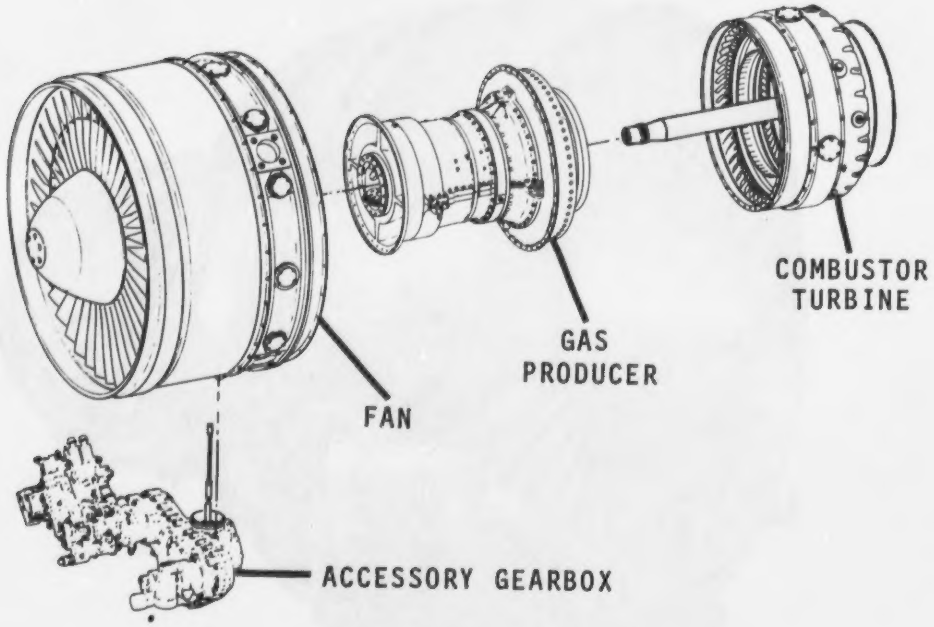


Figure 6-2. Engine Modules.

6.2 COMBUSTION SYSTEM

6.2.1 Description

The combustion system for the ALF-502 consists of a reverse-flow annular combustor with an air blast atomizing fuel injection system. This folded design permits maximum use of space and reduces engine length.

6.2.2 Combustor

The combustor includes a vortex-stabilized primary zone. The stabilizing vortices are formed by the air discharging from 28 cast radial inflow swirlers which have a fuel atomizer at each of their centers. Holes are placed in the liner sides at each swirler location to provide aerodynamic blockage and contain the toroid formed by the vortex in the primary zone.

In the intermediate zone, air is introduced to complete combustion and initiate dilution. This is done by means of sets of holes on the outer and inner liners.

The dilution zone includes additional holes distributed to meet radial circumferential temperature distribution requirements of the turbine.

Cooling of the liner walls is achieved by introducing a metered film of air and ensuring that it remains close to the walls.

The combustion products discharge into a curl that reverses the direction of flow to feed the turbine.

6.2.3 Fuel Injection System

The fuel injection system uses 28 air blast, main fuel injector nozzles with coaxial pressure atomizing pilot nozzles used primarily for engine light-off. The nozzles screw into a two-piece main fuel manifold having two separate internal passages.

A flow divider meters fuel to these nozzles in accordance with predetermined schedule of air blase versus pilot fuel flow, i.e., fuel passes through the flow divider and out to the pilot manifolds. The pressure drop across the flow divider creates a force that displaces a plunger that progressively opens the main flow metering ports and allows fuel to pass to the air blast fuel manifolds as engine fuel flow increases.

6.3 FUEL AND POWER CONTROL SYSTEM

6.3.1 General

The ALF 502 power control system (Figure 6-3) consists of three major subsystems:

- A gas producer fuel and power control
- An interstage air-bleed control system, and
- An inlet guide vane control system.

The fuel control is a hydromechanical type consisting essentially of the following main elements:

1. Fuel pump
2. Gas producer speed governor
3. Acceleration and deceleration control
4. Maximum fuel flow limiter
5. Main power lever and fuel shutoff valve
6. Compressor interstage air-bleed control
7. Inlet guide vane control.

The air-bleed and guide vane controls are actuated through fuel control signals to the respective actuators.

6.3.2 Gas Producer and Power Control System

The gas producer fuel and power control, with an integral fuel pump, is mounted directly to the accessory gearbox.

A gas producer speed governor regulates gas producer rotor speed to the value selected by the power lever over the range from ground idle to take-off thrust. Screw-type adjustments are provided to allow maximum and ground idle steady-state speed settings to be adjusted.

Acceleration fuel flow limits are scheduled over the entire operating range from starting to maximum gas producer speed by scheduling maximum fuel flow as a function of gas producer rotor speed, compressor discharge pressure, and fan inlet temperature. A deceleration schedule is provided to prevent engine flameout during deceleration. The absolute minimum fuel flow for deceleration or steady-state operation is determined by a minimum fuel flow stop that limits the closing of the main metering valve.

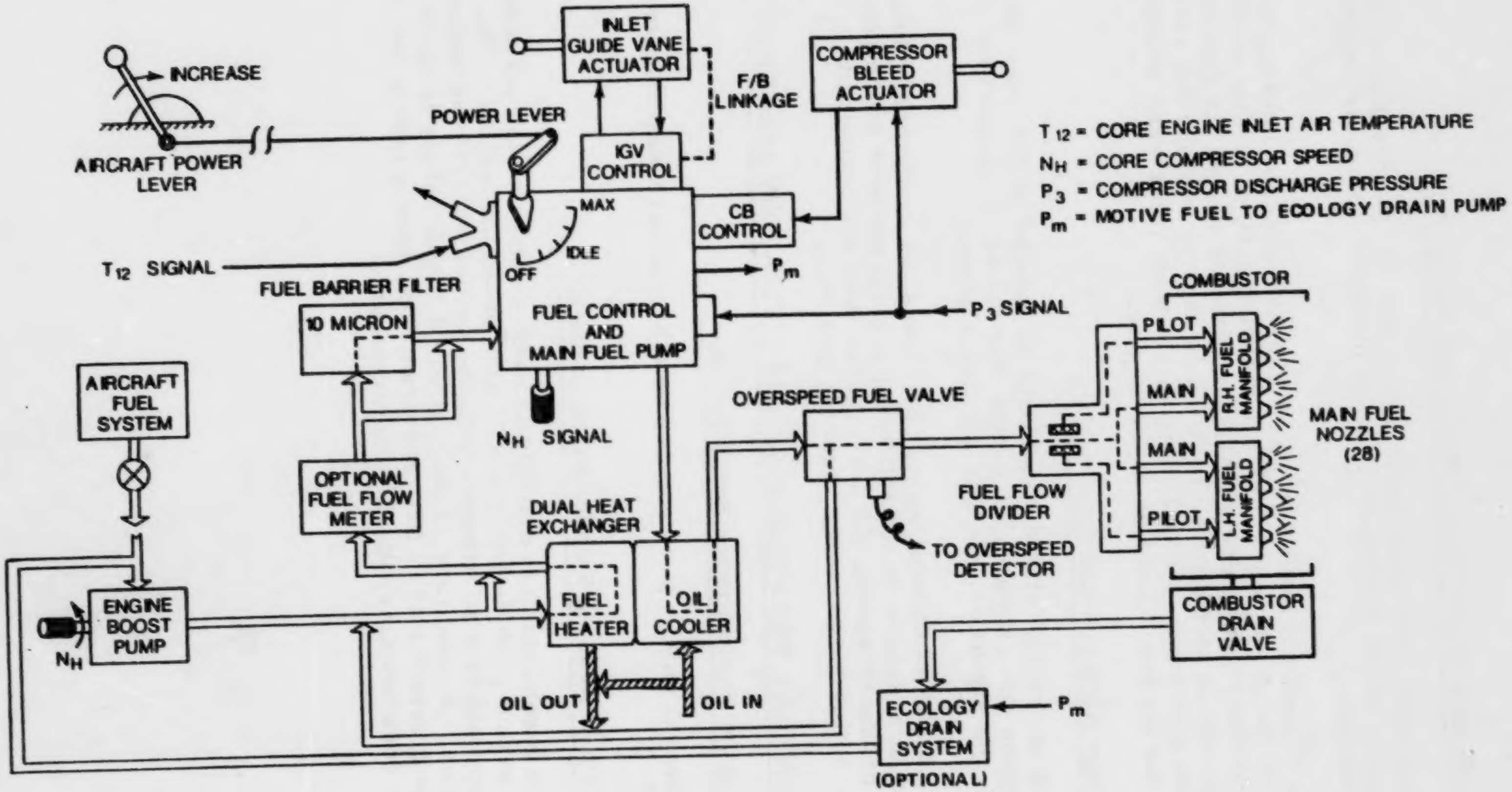

INCREASE
AIRCRAFT POWER LEVER
POWER LEVER
INLET GUIDE VANE ACTUATOR
F/B LINKAGE
COMPRESSOR BLEED ACTUATOR
IGV CONTROL
CB CONTROL
T_{12} = CORE ENGINE INLET AIR TEMPERATURE
N_H = CORE COMPRESSOR SPEED
P_3 = COMPRESSOR DISCHARGE PRESSURE
P_m = MOTIVE FUEL TO ECOLOGY DRAIN PUMP
MAX
IDLE
OFF
T_{12} SIGNAL
P_m
FUEL BARRIER FILTER
10 MICRON
FUEL CONTROL AND MAIN FUEL PUMP
P_3 SIGNAL
COMBUSTOR
PILOT
MAIN
MAIN
PILOT
R.H. FUEL MANIFOLD
L.H. FUEL MANIFOLD
MAIN FUEL NOZZLES (28)
AIRCRAFT FUEL SYSTEM
N_H SIGNAL
OVERSPEED FUEL VALVE
OPTIONAL FUEL FLOW METER
DUAL HEAT EXCHANGER
FUEL FLOW DIVIDER
TO OVERSPEED DETECTOR
ENGINE BOOST PUMP
N_H
FUEL HEATER
OIL COOLER
COMBUSTOR DRAIN VALVE
OIL OUT
OIL IN
ECOLOGY DRAIN SYSTEM
(OPTIONAL)
P_m

Figure 6-3. Power Control and Fuel System Schematic.

6.3.3 Variable Inlet Guide Vane Control and Actuator

The inlet guide vane control provides for positioning of the compressor inlet guide vanes in response to gas producer speed and engine inlet temperature.

An actuator mounted on the engine compressor housing is directly linked to the guide vanes by a synchronizing ring. While making the desired motion to the guide vanes, the actuator relays its position back to the control via an external feedback linkage to restore the servo valve to a null position. Adjustment of the inlet guide vane schedule is made within the feedback linkage on the engine.

6.3.4 Interstage Airbleed and Control

The interstage airbleed actuator is located on the rear flange of the core engine compressor. A single line delivers compressor discharge air for both the signal source and the power supply.

The airbleed control opens and closes the compressor interstage airbleed in response to the following signals present in the power control: (1) gas producer speed, (2) core engine inlet air temperature, (3) compressor outlet air pressure, and (4) fuel flow.

6.4 GENERAL PERFORMANCE SPECIFICATION AND EPAP VALUES DATA

6.4.1 Engine Performance Specifications

General engine performance data at standard-day sea level conditions given in Table 6-1.

6.4.2 1979 Emissions Standard Comparison

The combustor air distribution and airblast style fuel nozzles used in the ALF 502 engine provide low gaseous and smoke emissions. The present configuration approaches conformance with the projected 1979 emission limits for a T-1 class engine. A summary of the computed EPAP values is given in Table 6-2. The engine meets the 1979 NO_x requirements, barely meets the UHC requirements, but does not meet the CO requirements.

TABLE 6-1. GUARANTEED PERFORMANCE AT SEA LEVEL STATIC STANDARD DAY ATMOSPHERIC CONDITIONS (ALF 502D AND 502H ENGINES)

RATING	TOTAL NET THRUST (Minimum) (lb)	GAS GENERATOR ROTOR SPEED (Maximum) (rpm)	FAN ROTOR SPEED (Maximum) (rpm)	THRUST SPECIFIC FUEL CONSUMPTION (Maximum) (lb/hr/lb)	TOTAL AIRFLOW (lb/sec) ± 5%
Takeoff	6, 500	19, 639	7, 121	0. 417	235. 7
Maximum Climb	6, 170	19, 413	6, 988	0. 412	235. 7
Maximum Cruise	5, 675	19, 073	6, 780	0. 406	228. 3
Flight Idle	743 (Max)	13, 720	2, 890	458 lb/hr	86. 8
Ground Idle	400 (Max)	10, 300	1, 865	350 lb/hr	62. 5

NOTES:

1. The guaranteed performance values are consistent with the conditions specified in Model Specification with tailpipe and fan duct as shown in applicable figures and all losses associated therewith.

2. The above data is based on operation with no loading of accessory drives, zero customer bleed, and 100 percent inlet ram recovery.

TABLE 6-2. ENGINE EPAP CALCULATION AND COMPARISON WITH EPA 1979 REQUIREMENTS

ENGINE MODEL: ALF 502D , LF 02 T-1
COMBUSTOR S/V: 11.76 ft^{-1}

CLASS: T-1
VOLUME:

MAXIMUM POWER: 6500 lb/thrust
IDLE POWER: 400 lb/thrust
DATA SOURCE: EPA Test, August, 1976

CONFIGURATION: -46 Cert. Config.

MODE	P_3 Atm	T_3 °R	W_{ab} lb/sec	W_f lb/hr	W_f/W_{ab}	$W_f/W_{aex.}$		θ			UHC gm/kg	CO gm/kg	NO_x gm/kg	Smoke No.	η_b %
IDLE	2.25	715	7.9	370	.0130	.011		1.49			5.6	40.7	2.91	3	98.55
APPROACH	5.0	898	17.5	778	.0123	.0109		3.88			.57	11.0	5.88	9	99.68
CLIMBOUT	10.2	1120	30.0	2340	.0217	.0191		11.9			.11	0.5	9.37	25	99.99
TAKEOFF	11.1	1150	31.7	2650	.0232	.0205		13.7			.11	0.5	10.10	25	99.99
EPAP (from test results)											1.53	11.71	3.15		
EPAP (EPA 1979 requirements)											1.60	9.40	3.70		

Unless noted, fuel is Jet A, UHC = CH_4, NO_x = NO_2 All Values Referred to ISO Standard Day

CO - Carbon Monoxide
NO_x - Oxides of Nitrogren
UHC - Unburned Hydrocarbons
P_3 - Combustor Inlet Pressure
T_3 - Combustor Inlet Temperature
W_{ab} - Combustor Acutal Air Flow
W_f - Fuel Flow
W_f/W_{ab} - Combustor Fuel-Air Ratio
$W_f/W_{aex.}$ - Exhaust Fuel-Air Ratio

η_b - Combustor Efficiency
S/V - Surface Area/Volume
θ - Theta Correlation Parameter = $(P_3^{1.75}/Wa)*$
Exp $(T_3/534.3)$ $AD^{.75}$

Where
A = Area
b = $\sqrt{4A/\pi}$

7.0 TEST-POINT SELECTION

7.1 ENGINE TEST

The ALF 502 turbofan engine has a standard-day rating of 6500 pounds thrust. At ambient conditions other than a standard-day, thrust and turbine temperature limitations are placed on engine operation to maintain the mechanical integrity of the components.

During actual aircraft operation except at idle, the exhaust gas temperature (T4.1) and fan rotor speed, N_{II}, are maintained within the specification limits of the particular engine. A constant maximum N_{II} directly relates to a constant maximum thrust, therefore, at temperatures below 15°C (59°F), while the EGT limit will not be reached, the thrust is not to exceed the 6500-pound rating.

The turbine hardware operating temperature limits require that the maximum EGT specified with the engine not be exceeded during operation. As the inlet temperature increases above 15°C, the maximum thrust is reduced proportionally to maintain a tolerable condition in the hot section. During this test program, the ambient temperature was greater than 15°C, thus EGT and not thrust was the limiting parameter.

The EGT/thrust characteristic of the engine was defined prior to the emission program by an engine calibration to determine the thrust-temperature characteristic. The idle and 1 1/2 idle performance was checked at a constant 400-pound and 600-pound thrust to be consistent with aircraft operation.

Two calibration runs were performed, one with and one without the gas emission probe in place at the tailpipe exhaust. The effect of the probe could then be determined and compensations made, if necessary.

The data from the $T_{4.1}$ harness, consisting of eight thermocouples at the power turbine inlet, was obtained for each of the power conditions. A correction of the temperature data to standard day condition was made for each value by $\theta^{1.022}$ (θ = Tamb/518.688). This correction factor, in lieu of the standard differential parameter ($\theta^{1.0}$), was developed for a range of ambient temperatures using an engine simulation program that accounts for changes in the air and gas properties, the engine rematch caused by the air and gas property changes, and the component performance changes caused by the rematch. The resulting values were then plotted (Figure 7-1) against referred thrust (F_N/δ). The probe effect was small but noticeable at the higher thrust levels. The thrust levels to be investigated were idle (400 lb), 1-1/2 idle (600 lb), approach (1950 lb), cruise 1 (2900 lb), cruise 2 (3200 lb), climbout (5850 lb), and takeoff (6500 lb). The two cruise conditions were to cover the range of the expected maximum power condition that could be duplicated during the combustor rig test.

From Figure 7-1, gas temperatures for approach through takeoff were obtained. The engine power setting was to be adjusted to achieve these values regardless of inlet temperature conditions for each day's emission test.

7.2 COMBUSTOR RIG TEST

The combustor rig test conditions were selected, where possible, to duplicate the combustor environment present in the engine. Considerations for the rig test facility limitations and local weather conditions were required in the selection of the test points simulating the higher power settings.

The idle, 1 1/2 idle, approach, and 2900-lb thrust conditions were within the capabilities of the system. Both 2900-pound and 3200-pound thrust points were chosen for the engine test (completed first) to allow possible rig operation at the higher level if the facility limits could be satisfactorily extended.

Based on past humidity information recorded by the National Weather Service, 25 grains were selected as the minimum condition consistently achieveable for the test since no air drying capability was available. Also, the ambient temperature and barometer were considered in the point selection.

The facility cooling and heating capacity limited the high-flow cold-day simulations on warmer ambient days and warm humid-day simulation on cold dry days. The additional heat capacity required to evaporate large quantities of water injected into the system for humidification required consideration in the selection process.

An engine simulation computer program was used to generate the combustor parameters for a typical engine operating on a standard day at selected power levels. This program uses component performance data and a matching technique to develop the values of interest.

The core compressor airflow at each power condition was adjusted to compensate for the turbine cooling air extraction and interstage bleed air at the idle and 1 1/2 idle points. The nominal turbine cooling airflow of 11 percent was to be used in computing the rig combustor airflow, and a nominal value of 13 percent was applied to the airflow data for compressor bleed.

The standard-day pressures, temperatures, and air and fuel flows were adjusted to each of the ambient conditions to be simulated. The referral factors used are defined in Table 7-1, and tabulation of the data points and resulting conditions to be investigated are shown in Table 7-2.

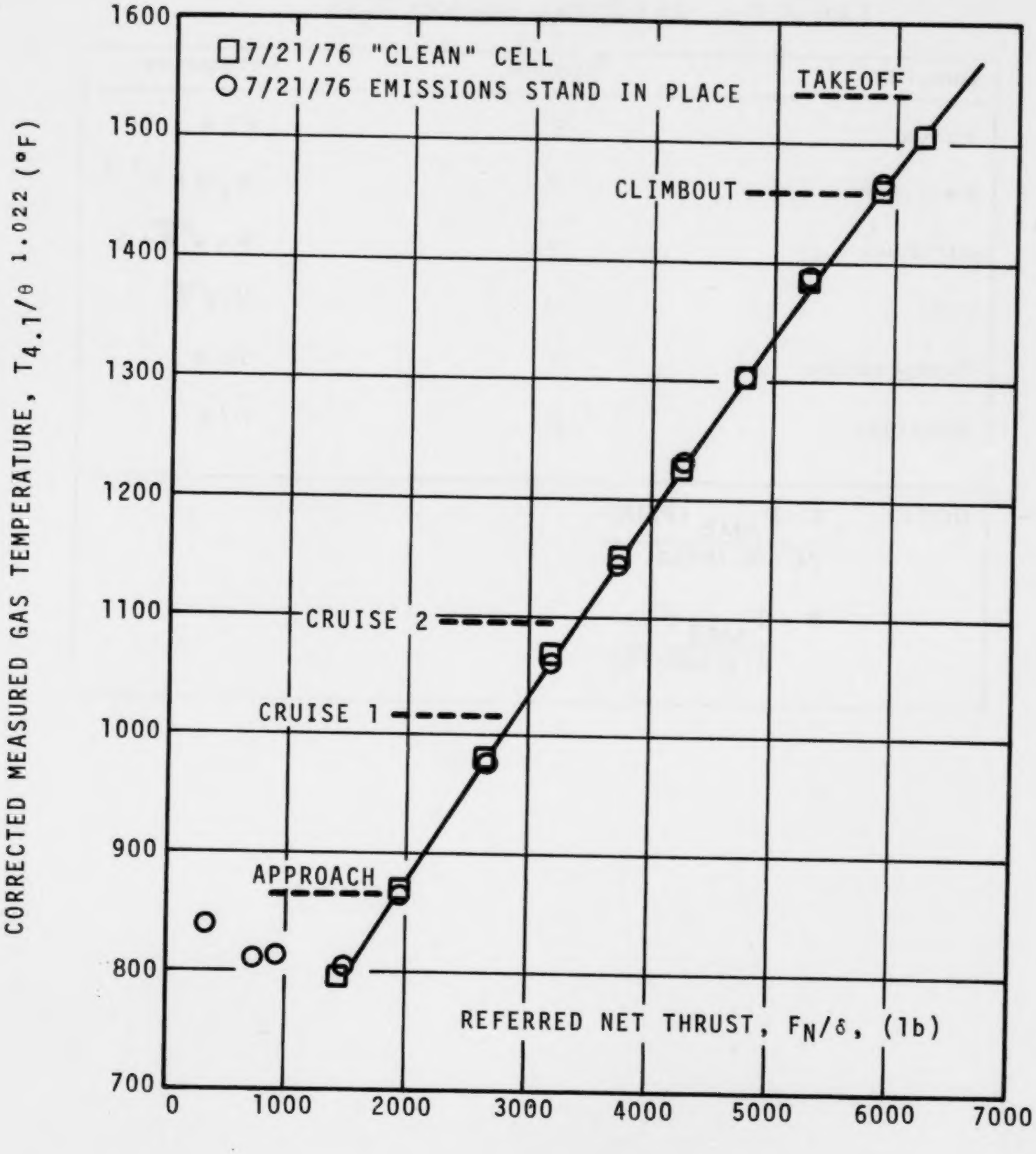


Figure 7-1. ALF 502 Corrected Measured Gas Temperature Versus Referred Net Thrust.

TABLE 7-1. REFERRAL PARAMETERS

Quantity	Symbol	Parameter
Thrust	F	F/δ
Fuel Flow	W_f	$W_f/\delta\theta^{.712}$
Air Flow	Wa	$Wa\sqrt{\theta}/\delta$
RPM	M	$N/\sqrt{\theta}$
Temperature	T	T/θ
Pressure	P	P/δ

NOTE: $\delta = \dfrac{P_{AMB}\ (PSIA)}{14.696\ (PSIA)}$

$\theta = \dfrac{T_{AMB}\ (^{o}R)}{518.688(^{o}R)}$

TABLE 7-2. COMBUSTOR RIG TEST CONDITIONS

DATA Pt No.	TO (°R)	PO (in Hg)	T3 (°F)	P3 (psia)	Wa (pps)	GR. H_2O/ LB AIR	W_f (pph)	A/F	EQUIV. THRUST (lb)
001145	519	29.92	225	35	7.25	44	350	74.6	400
002145	519	29.92	285	40	10.5	44	420	90	600
003144	519	29.92	440	75	17.8	44	790	81.1	1950
0041x4	519	29.92	502	96	21.0	44	1130	66.9	2900
0071x4	519	29.92	424	96	21.0	44	1680	45	5850
0081x4	519	29.92	414	96	21.0	44	1802	42	6500
191135	479	25.98	173	30.4	6.55	25	287	82.2	400
011135	479	29.92	173	35	7.55	25	331	82.2	400
151135	479	32.28	173	37.8	8.14	25	357	82.2	400
021135	499	29.92	199	35	7.39	25	340	78.2	400
061135	499	29.92	199	35	739	35	340	78.2	400
201145	519	25.98	225	30.4	6.29	52.5	304	74.6	400
031135	519	29.92	225	35	7.25	25	350	74.6	400
071145	519	29.92	225	35	7.25	52.5	350	74.6	400
1011x4	519	29.92	225	35	7.25	70.	350	74.6	400
161145	519	32.28	225	37.8	7.82	52.5	378	74.6	400
192135	479	25.98	228	34.7	9.5	25	344	99.2	600
012135	479	29.92	228	40	10.93	25	397	99.2	600
152135	479	32.28	228	43.2	11.79	25	428	99.2	600
022135	499	29.92	257	40	10.71	25	408	94.4	600
062145	499	29.92	257	40	10.71	35	408	94.4	600
041135	545	29.92	260	35	7.07	25	362	70.3	400
081145	545	29.92	260	35	7.07	52.2	362	70.3	400
111145	545	29.92	260	35	7.07	105	362	70.3	400
131145	545	29.92	260	35	7.07	175	362	70.3	400
202145	519	25.98	285	34.7	9.12	52.5	364	90	600
032135	519	29.92	285	40	10.5	25	420	90	600
072145	519	29.92	285	40	10.5	52.5	420	90	600
102145	519	29.92	285	40	10.5	70	420	90	600
162145	519	32.28	285	43.2	11.33	52.5	453	90.	600
211135	565	25.98	286	30.4	6.03	25	323	67.3	400
221145	565	25.98	286	30.4	6.03	175	323	67.3	400
051135	565	29.92	286	35	6.95	25	372	67.3	400
091145	565	29.92	286	35	6.95	52.5	372	67.3	400
121145	565	29.92	286	35	6.95	105	372	67.3	400
141145	565	29.92	286	35	6.95	175	372	67.3	400
171135	565	32.28	286	37.8	7.5	25	401	67.3	400
181145	565	32.28	286	37.8	7.5	175	401	67.3	400
042135	545	29.92	323	40	10.24	25	435	84.8	600

TABLE 7-2. COMBUSTOR RIG TEST CONDITIONS (Cont'd)

DATA Pt No.	TO (°R)	PO (in Hg)	T3 (°F)	P3 (psia)	Wa (pps)	GR. H_2O/ LB AIR	W_f (pph)	A/F	EQUIV. THRUST (lb)
082145	545	29.92	323	40	10.24	52.5	435	84.8	600
112145	545	29.92	323	40	10.24	105	435	84.8	600
132145	545	29.92	323	40	10.24	175	435	84.8	600
212135	565	25.98	351	34.7	8.74	25	387	81.2	600
222145	565	25.98	351	34.7	8.74	175	387	81.2	600
052135	565	29.92	351	40	10.1	25	446	81.2	600
092145	565	29.92	351	40	10.1	52.5	446	81.2	600
122145	565	29,92	351	40	10.1	105	446	81.2	600
142145	565	29.92	351	40	10.1	175	446	81.2	600
172135	565	32.28	351	43.2	10.9	25	482	81.2	600
182155	565	32.28	351	43.2	10.9	175	482	81.2	600
1981x4	479	25.98	345	83.4	19.0	25	1478	46.2	6500
0181x4	479	29.92	345.	96	21.85	25	1701	46.2	6500
1581x4	479	32.28	345	103.6	23.58	25	1835	46.2	6500
193134	479	25.98	371	65.1	16.1	25	648	89.4	1950
013144	479	29.92	371	75	18.53	25	746	89.4	1950
153144	479	32.28	371	80.9	20.0	25	805	89.4	1950
0281x4	499	29.92	380	96.	21.42	25	1753	44.	6500
0681x4	499	29.92	380	96.	21.42	35	1753	44.	6500
023134	499	29.92	405	75.	18.2	25	768	85.1	1950
063144	499	29.92	405	75.	18.2	35	768	85.1	1950
2081x4	519	25.98	414	83.4	18.23	52.5	1564	42.	6500
0381x4	519	29.92	414	96	21.	25	1802	42.	6500
0781x4	519	29.92	414	96	21.	52.5	1802	42.	6500
1081x4	519	29.92	414	96	21.	70	1802	42.	6500
1681x4	519	32.28	414	103.6	22.6	52.5	1945	42.	6500
1941x4	479	25.98	428	83.4	19.0	25	927	73.7	2900
0141x4	479	29.92	428	96	21.85	25	1067	73.7	2900
1541x4	479	32.28	428	103.6	23.58	25	1151	73.7	2900
203144	519	25.98	440	65.1	15.46	52.5	686	81.1	1950

TABLE 7-2. COMBUSTOR RIG TEST CONDITIONS (Cont'd)

DATA Pt No.	TO (°R)	PO (in Hg)	T3 (°F)	P3 (psia)	Wa (pps)	GR. H_2O/ LB AIR	W_f (pph)	A/F	EQUIV. THRUST (lb)
033134	519	29.92	440	75	17.8	25	790	81.1	1950
073144	519	29.92	440	75	17.8	52.5	790	81.1	1950
103144	519	29.92	440	75	17.8	70	790	81.1	1950
163144	519	32.28	440	80.9	19.2	52.5	852	81.1	1950
0461x4	545	29.92	464	96	20.5	25	1734	42.6	5780
0861x4	545	29.92	464	96	20.5	52.5	1734	42.6	5780
1161x4	545	29.92	464	96	20.5	105	1734	42.6	5780
1361x4	545	29.92	464	96	20.5	175	1734	42.6	5780
0241x4	499	29.92	465	96	21.42	25	1098	70.2	2900
0641x4	499	29.92	465	96	21.42	35	1098	70.2	2900
0431x4	545	29.92	485	75	17.36	25	818	76.4	1950
063134	545	29.92	485	75	17.36	52.5	818	76.4	1950
113144	545	29.92	485	75	17.36	105	818	76.4	1950
133154	545	29.92	485	75	17.36	175	818	76.4	1950
2151x4	565	25.98	495	83.4	17.47	25	1463	43.	5285
2251x4	565	25.98	495	88.4	17.47	175	1463	43	5285
0551x4	565	29.92	495	96	20.13	25	1686	43.	5285
0951x4	565	29.92	495	96	20.13	52.5	1686	43.	5285
1251x4	565	29.92	495	96	20.12	105	1686	43.	5285
1451x4	565	29.92	495	96	20.13	175	1686	43	5285
1751x4	565	32.28	495	103.6	21.7	25	1818	43	5285
1851x4	565	32.28	495	103.6	21.7	175	1818	43.	5285
2041x4	519	25.98	502	83.4	18.23	52.5	981	66.9	2900
0341x4	519	29.92	502	96	21.	25	1130	66.9	2900
0741x4	519	29.92	502.	96	21.	52.5	1130.	66.9	2900
104134	519	29.92	502.	96	21.	70	1130	66.9	2900
1641x4	519	32.28	502	103.6	22.6	52.5	1219	66.9	2900
2131x4	565	25.98	520	65.1	14.8	25	729	73.2	1950
223154	565	25.98	520	65.1	14.8	175	729	73.2	1950
0531x4	565	29.92	520	75	17.1	25	839	73.2	1950
093134	565	29.92	520	75	17.1	52.5	839	73.2	1950
123144	565	29.92	520	75	17.1	105	839	73.2	1950
143154	565	29.92	520	75	17.1	175	839	73.2	1950
1731x4	565	32.28	520	80.9	18.4	25	906	73.2	1950
183154	565	32.28	520	80.9	18.4	175	906	73.2	1950
0441x4	545	29.92	550	96	20.5	25	1170	63.1	2900
0841x4	545	29.92	550	96	20.5	52.2	1170	63.1	2900
114144	545	29.92	550	96	20.5	105	1170	63.1	2900

TABLE 7-2. COMBUSTOR RIG TEST CONDITIONS (Cont'd)

DATA Pt No.	TO (°R)	PO (in Hg)	T3 (°F)	P3 (psia)	Wa (pps)	GR. H_2O/ LB AIR	W_f (pph)	A/F	EQUIV. THRUST (lb)
1341x4	545	29.92	550	96	20.5	175	1170	63.1	2900
2141x4	565	25.98	587	83.4	17.47	25	1042	60.4	2900
2241x4	565	25.98	587	83.4	17.47	175	1042	60.4	2900
0541x4	565	29.92	587	96	20.13	25	1299	60.4	2900
0941x4	565	29.92	587	96	20.13	52.5	1200	60.4	2900
1241x4	565	29.92	587	96	20.13	105	1200	60.4	2900
1441x4	565	29.92	587	96	20.13	175	1200	60.4	2900
1741x4	565	32.28	587	103.6	21.7	25	1295	60.4	2900
1841x4	565	32.28	587	103.6	21.7	175	1295	60.4	2900

Data Point Number Code

Digits 1 & 2 - Test Condition (Ref Table 2-3)

Digits 3 & 4 - Simulated Power Level

Digit 5 - Water Element, Lo=3, M=4, H=5 (Note X Indicates Point Not Run)

Digit 6 - Fuel Element (M=5 H=4)

NOTE: Due to extrapolation diffiluties in determining the low power air flows, the idle and 1.5 idle fuel-air ratios run during the combustor rig tests do not correspond to the actual engine conditions (rig idle was 11% to rich and rig 1.5 idle 11% to lean)

8.0 MEASUREMENT TECHNIQUES AND EQUIPMENT

8.1 GENERAL

The instrumentation techniques and data acquisition systems used for the emissions program were selected to assure that accurate quality measurements could be achieved in both the combustor rig and engine tests. The goals were twofold, i.e., one to measure the aerothermodynamic parameters and the second to determine the combustor emissions. Sensors to measure the desired temperatures, pressures, and flows and probes to extract samples for emissions and humidity measurements were specially designed for their location and application. Lycoming-designed automatic data recording and measuring systems were extensively used for data management. Final computation and compilation was accomplished at Lycoming's main computer center.

8.2 EMISSIONS MEASUREMENTS

Engine exhaust and combustor rig emissions were measured with equipment and procedures conforming to present EPA regulations as defined in Title 40, Part 87 of the Federal Register. The methods defined were expanded and modified slightly, primarily to encompass the combustor rig tests, as indicated in the correspondence included in Appendix A.

Different probe designs were used in the engine and rig tests because of the sampling plane locations and thermal conditions. The same Lycoming emission-measurement system was used in both tests to assure consistency of results.

8.3 ENGINE EMISSION SAMPLING PROBE

The engine exhaust emissions sampling probe (Figure 8-1) consists of two sets of four legs that are equally spaced circumferentially with three sample holes per leg. This probe assembly is made in conformance with Lycoming P/N TE28008 (Figure 8-2). During the test, only the forward set of legs was used for both smoke and gaseous emissions sampling.

Each of the three sample holes in each leg was 1.143 mm (0.045 inch) in diameter, giving a total area of 13.55 mm^2 (0.021 in.^{2}) for the twelve holes. These dimensions were chosen to be compatible with the system pumping capacity in achieving over 80 percent of the system pressure loss in the probe and to assure a large enough area to resist contaminant clogging. The holes in each leg were located at centers of equal geometric areas, a condition that Lycoming has found to give representative results within 10 percent as reported by Rubins

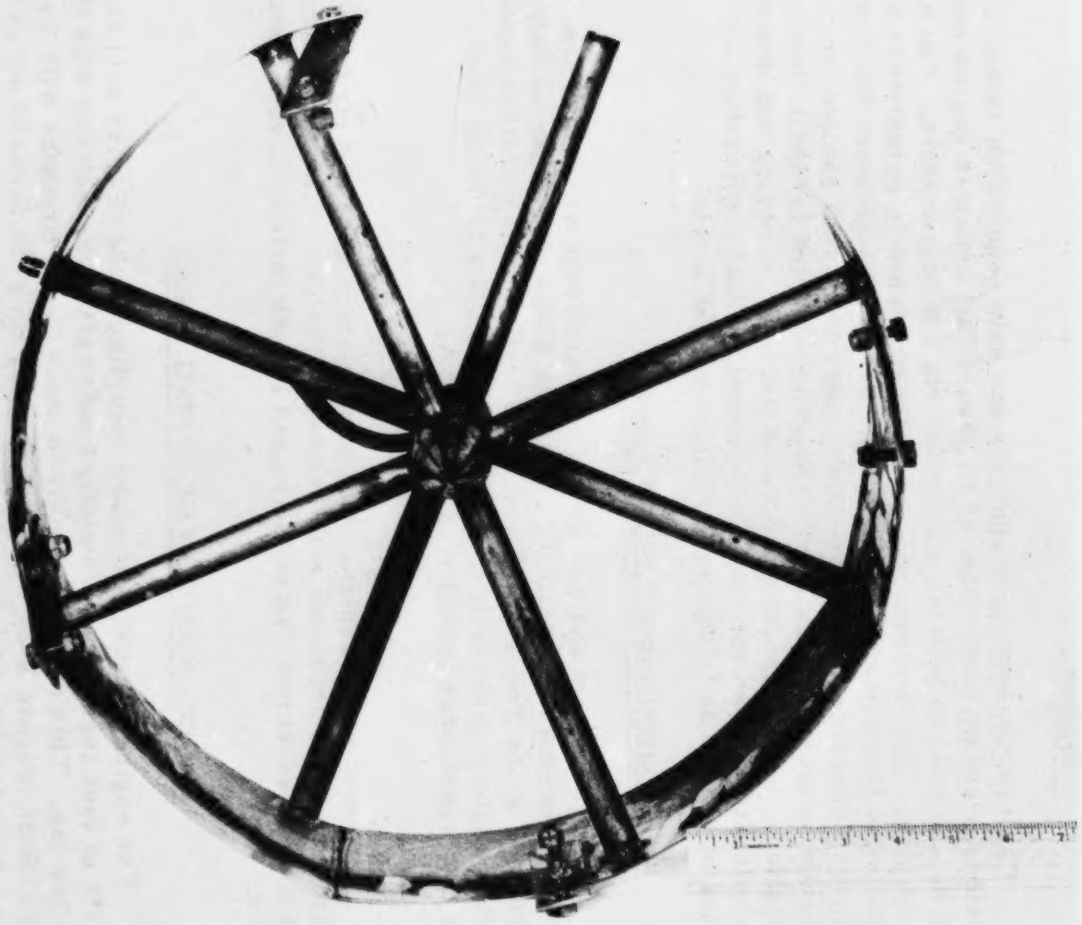


Figure 8-1. Engine Exhaust Averaging Gas Sample Probe.

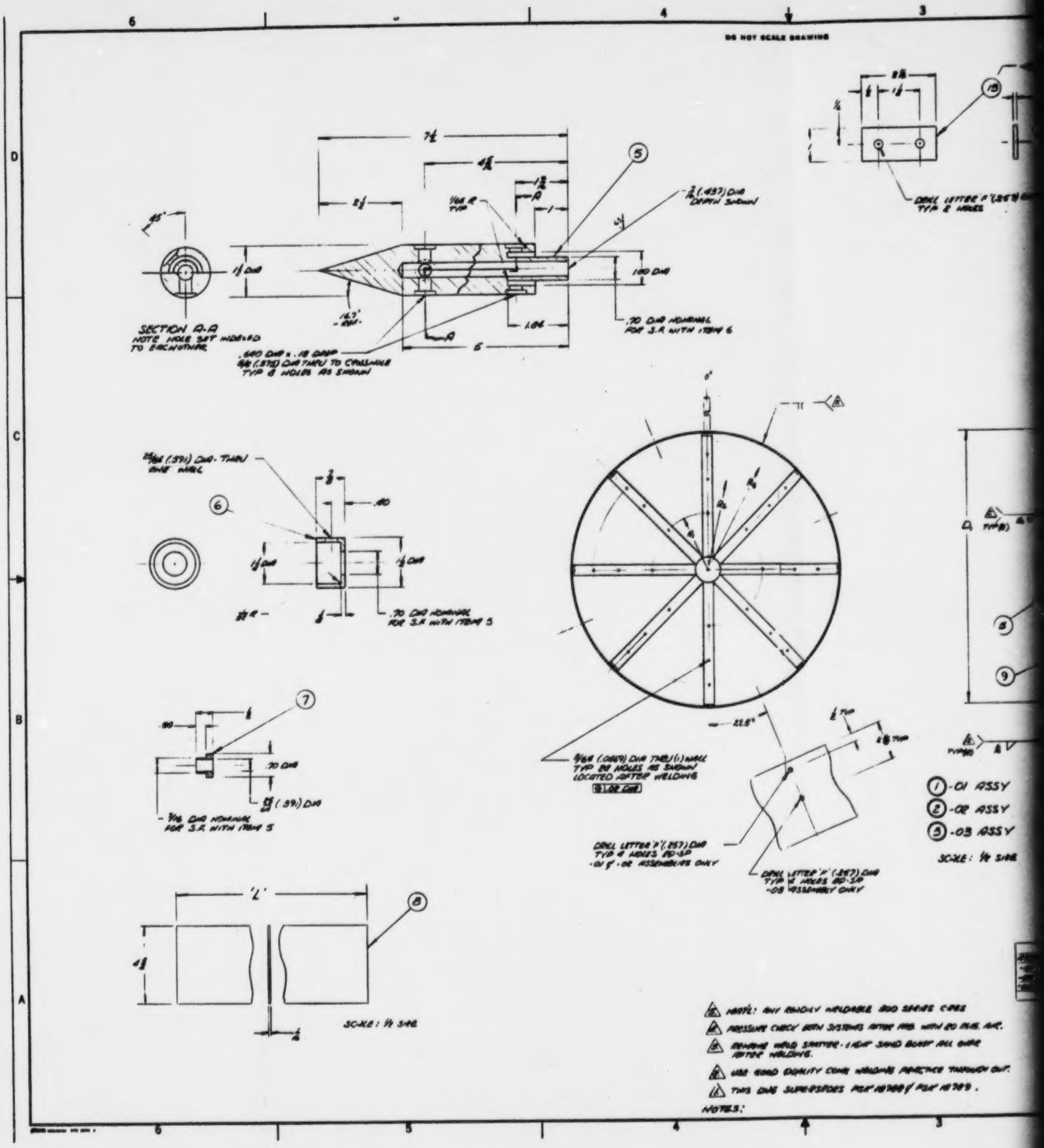
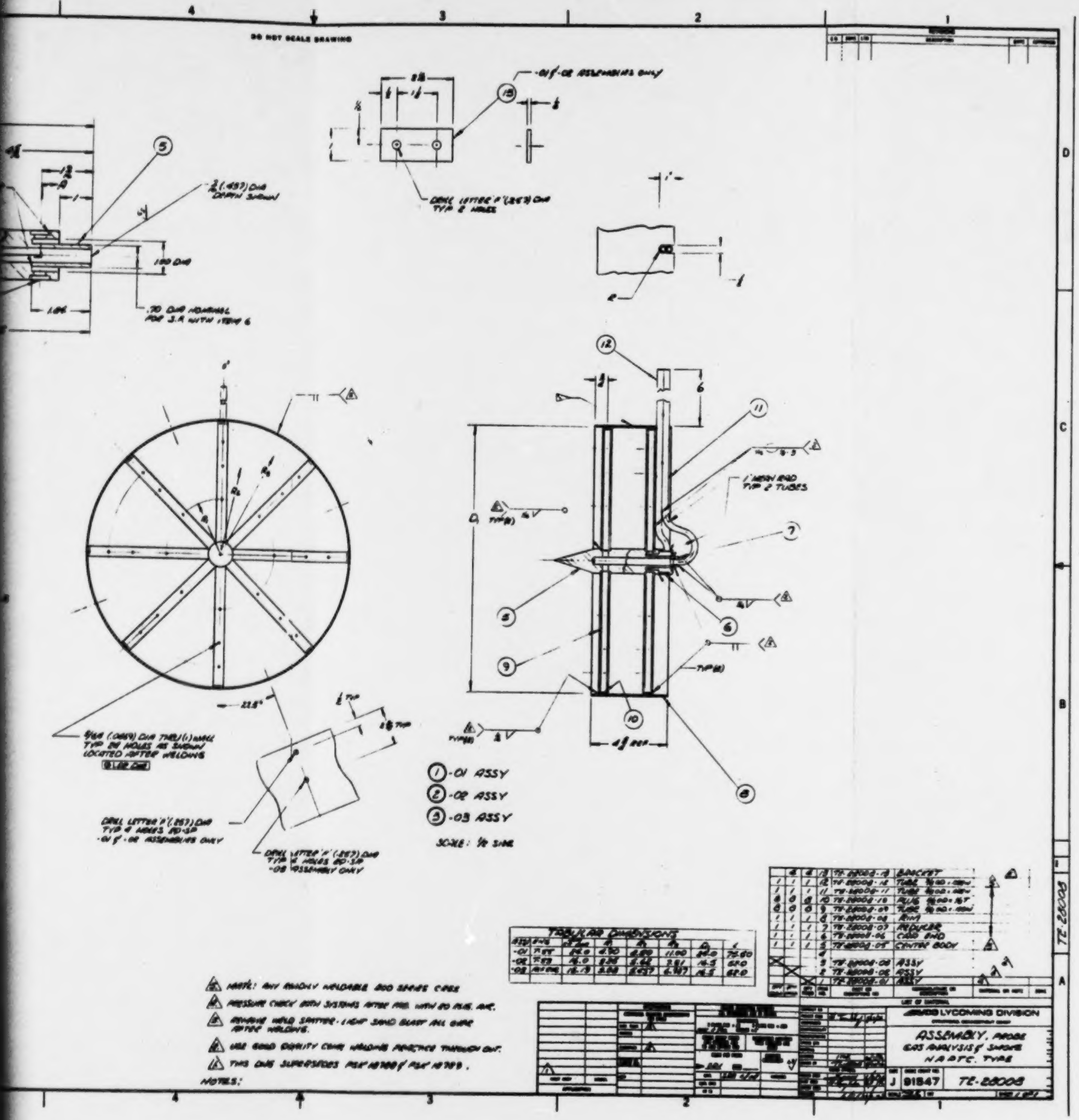

DO NOT SCALE DRAWING
SECTION A-A
NOTE HOLE SET INDEXED TO EACH OTHER
①-01 ASSY
②-02 ASSY
③-03 ASSY
SCALE: ½ SIZE
SCALE: ½ SIZE
MATL: ANY READILY WELDABLE 300 SERIES CRES
PRESSURE CHECK BOTH SYSTEMS AFTER FAB. WITH 80 PSIG. AIR.
REMOVE WELD SPATTER - LIGHT SAND BLAST ALL OVER AFTER WELDING.
USE GOOD QUALITY CONE WELDING PRACTICE THROUGH OUT.
NOTES:

Figure 8-2. Engine Gas Sample Probe Drawing - Lycoming P/N TE 28008.


DO NOT SCALE DRAWING
-01 & -02 ASSEMBLIES ONLY
DRILL LETTER F (.257) DIA TYP 2 HOLES
(.257) DIA DEPTH SHOWN
1.00 DIA
.70 DIA NOMINAL FOR S.A. WITH ITEM 6
1.86
1" MEAN RAD TYP 2 TUBES
TYP (8)
D₁
6
22.5°
4 7/8 REF
5/64 (.0469) DIA THRU (1) WALL TYP 24 HOLES AS SHOWN LOCATED AFTER WELDING
DRILL LETTER F (.257) DIA TYP 4 HOLES EQ-SP -01 & -02 ASSEMBLIES ONLY
DRILL LETTER F (.257) DIA TYP 4 HOLES EQ-SP -03 ASSEMBLY ONLY
① -01 ASSY
② -02 ASSY
③ -03 ASSY
SCALE: 1/2 SIZE
5
6
7
8
9
10
11
12
13
D
C
B
A
4
3
2
1

TABULAR DIMENSIONS

ASSY	[illegible]	[illegible]	R₁	R₂	R₃	θ	ℓ
-01	[illegible]	22.0	4.50	8.50	11.00	60.0	75.00
-02	[illegible]	16.0	2.50	5.44	7.81	14.5	62.0
-03	[illegible]	16.13	3.00	5.037	6.187	14.5	62.0

	4	4	13	TE-28008-13	BRACKET
1	1	1	12	TE-28008-12	TUBE [illegible]
1	1	1	11	TE-28008-11	TUBE [illegible]
8	8	8	10	TE-28008-10	PLUG [illegible]
8	8	8	9	TE-28008-09	TUBE [illegible]
1	1	1	8	TE-28008-08	RIM
1	1	1	7	TE-28008-07	REDUCER
1	1	1	6	TE-28008-06	CASE END
1	1	1	5	TE-28008-05	CENTER BODY
			4		
			3	TE-28008-03	ASSY
			2	TE-28008-02	ASSY
			1	TE-28008-01	ASSY

LIST OF MATERIAL

NOTES:

1. MATL: ANY READILY WELDABLE 300 SERIES CRES
2. PRESSURE CHECK BOTH SYSTEMS AFTER FAB. WITH 80 PSIG. AIR.
3. REMOVE WELD SPATTER - LIGHT SAND BLAST ALL OVER AFTER WELDING.
4. USE GOOD QUALITY CRES WELDING PRACTICE THROUGH OUT.
5. THIS DWG SUPERSEDES PSK 18788 & PSK 18789.

AVCO LYCOMING DIVISION

ASSEMBLY, PROBE
GAS ANALYSIS & SMOKE
NAPTC. TYPE

J 91847 TE-28008

TE-28008

and Doyle (1).

8.4 COMBUSTOR RIG EMISSION SAMPLING PROBE

The combustion rig emissions sampling probe assembly (Figure 8-3) consists of eight individual probes (Figure 8-4) manifolded to a central collection tube. The individual probes are liquid cooled to promote chemical-reaction quenching of the sample and to provide the required endurance life at combustor exit temperature levels. The individual probes are made in conformance with Lycoming P/N TE28010-01 (Figure 8-5).

The eight gas sample probes were mounted as an assembly in the test rig instrument drum at equally spaced increments in the plane of the first turbine nozzle inlet. Each probe consisted of five manifolded 0.483 mm (.019 inch)ports at centers of equal geometric areas and a cooling fluid inlet and outlet port. The probes were connected to a triple manifold system mounted to the instrument drum. The manifold provided the cooling fluid path to each of the probes and the return flow through a second path. The third manifold route was used for sample extraction.

The larger number of 40 sample holes in the rig, versus only 12 in the engine, has been found necessary to provide a representative sample at the combustor exit plane where conditions are less homogeneous.

8.5 GASEOUS EMISSIONS MEASUREMENT DATA SYSTEM DS18

The DS18 emission system is a portable unit used for engine and combustor tests to measure the various constituents of the exhaust, including hydrocarbons, carbon monoxide, carbon dioxide, and oxides of nitrogen. All instruments and sampling techniques are consistent with the procedures established by the Environmental Protection Agency and published in Title 40, Part 87 of the Federal Register.

The system is configured to three basic types of gas analyzing instruments. A flame ionization (FID)-type detector is used for total hydrocarbon (THC) content; chemiluminescence detection methods are used for oxides of nitrogen; and non-dispersive infrared detection (NDIR) is used for carbon monoxide and carbon dioxide.

8.5.1 Hydrocarbon Analyzer

The hydrocarbon analyzer is a Varian Aerograph™, model 1400 gas chromatograph with an FID detector. The operation of the of the instrument

---

(1) T53 and T55 Gas Turbine Combustor and Engine Exhaust Emission Measurements by Philip Rubins and Brian W. Doyle, USAAMRDL Tech Report 73-47 December 1973.

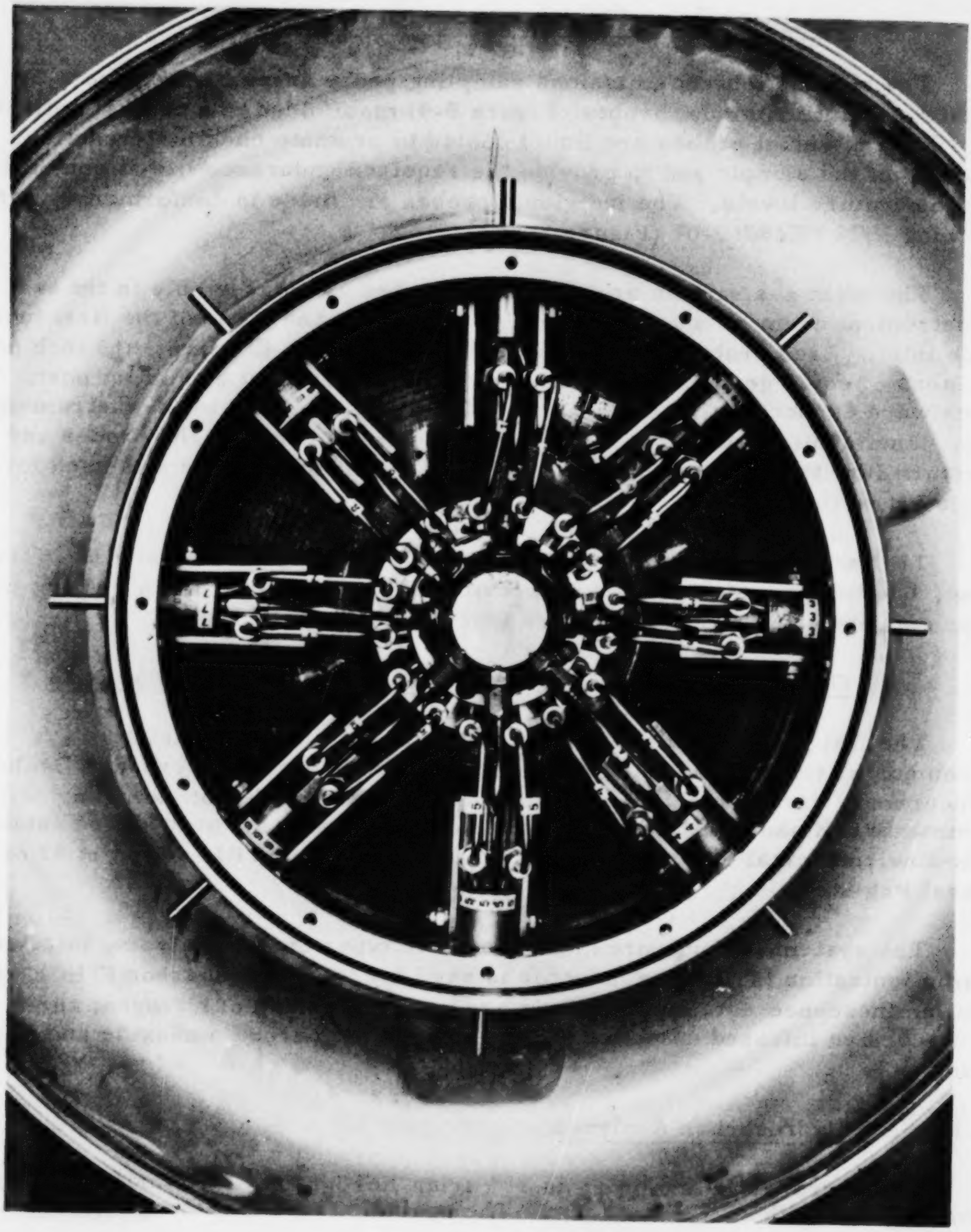


Figure 8-3. Combustor Rig Gas Sample Probe Assembly.

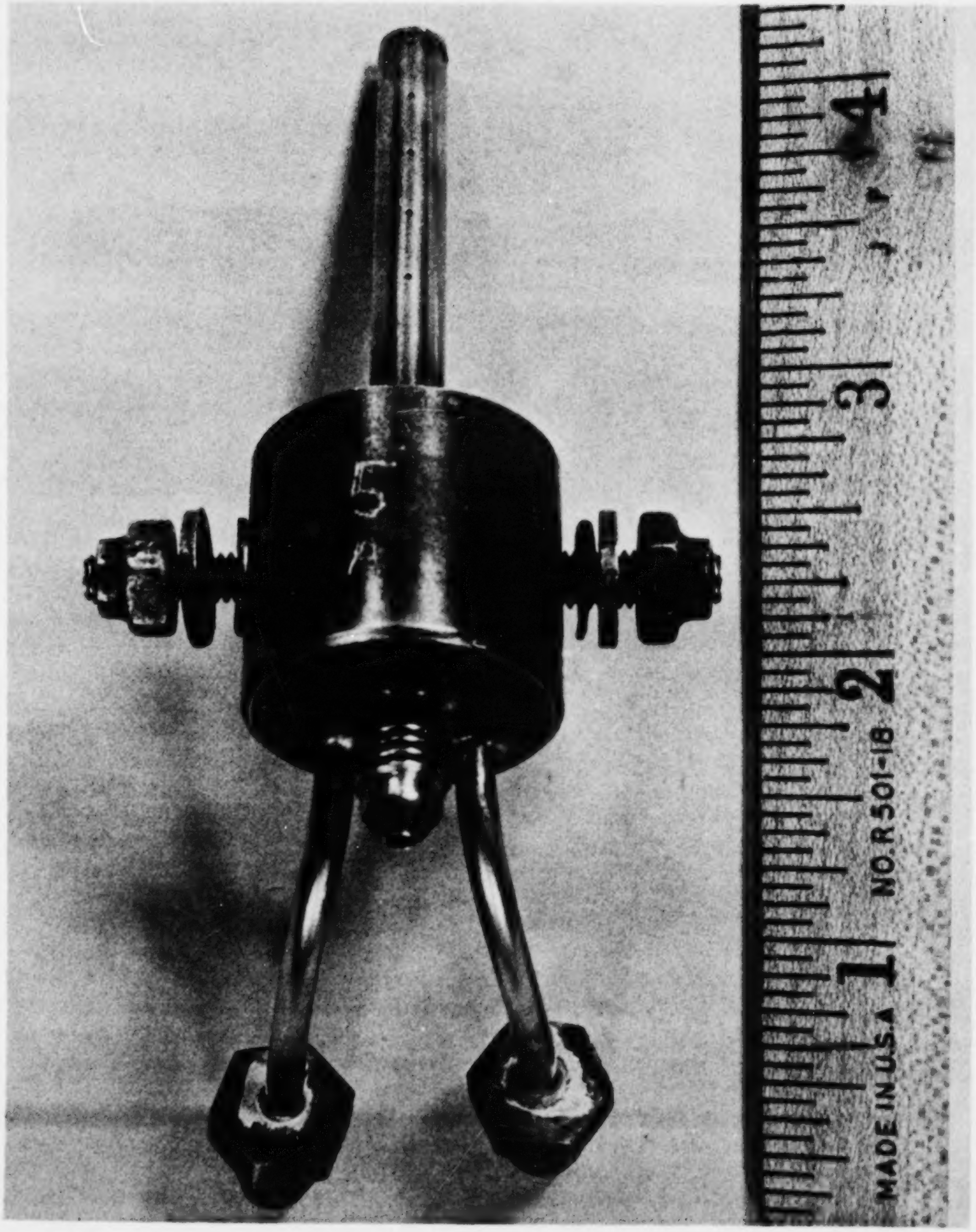

5
MADE IN U.S.A
NO. R 501-18
1
2
3
4

Figure 8-4. Combustor Rig Gas Sample Probe - TE 28010-01.

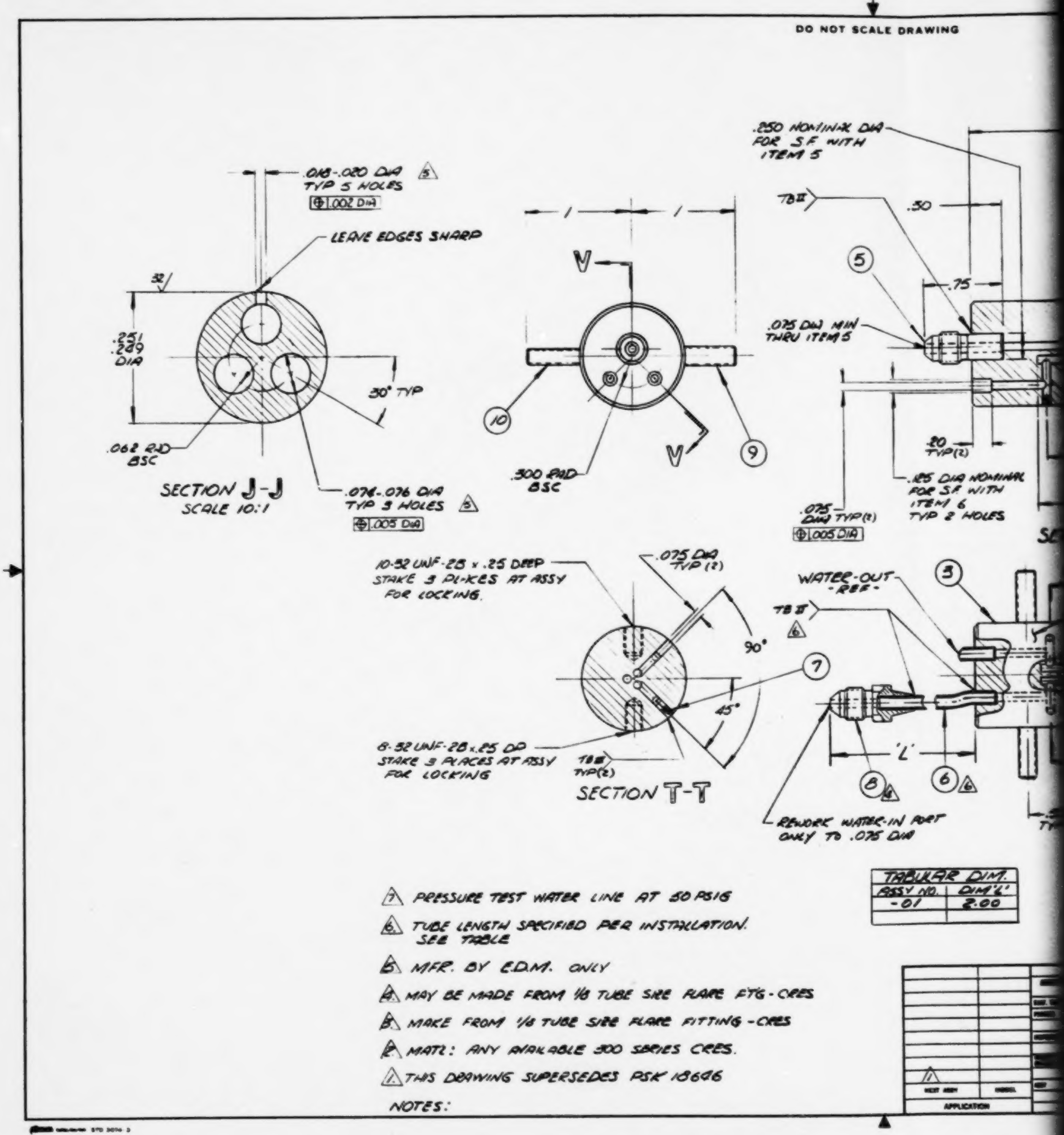
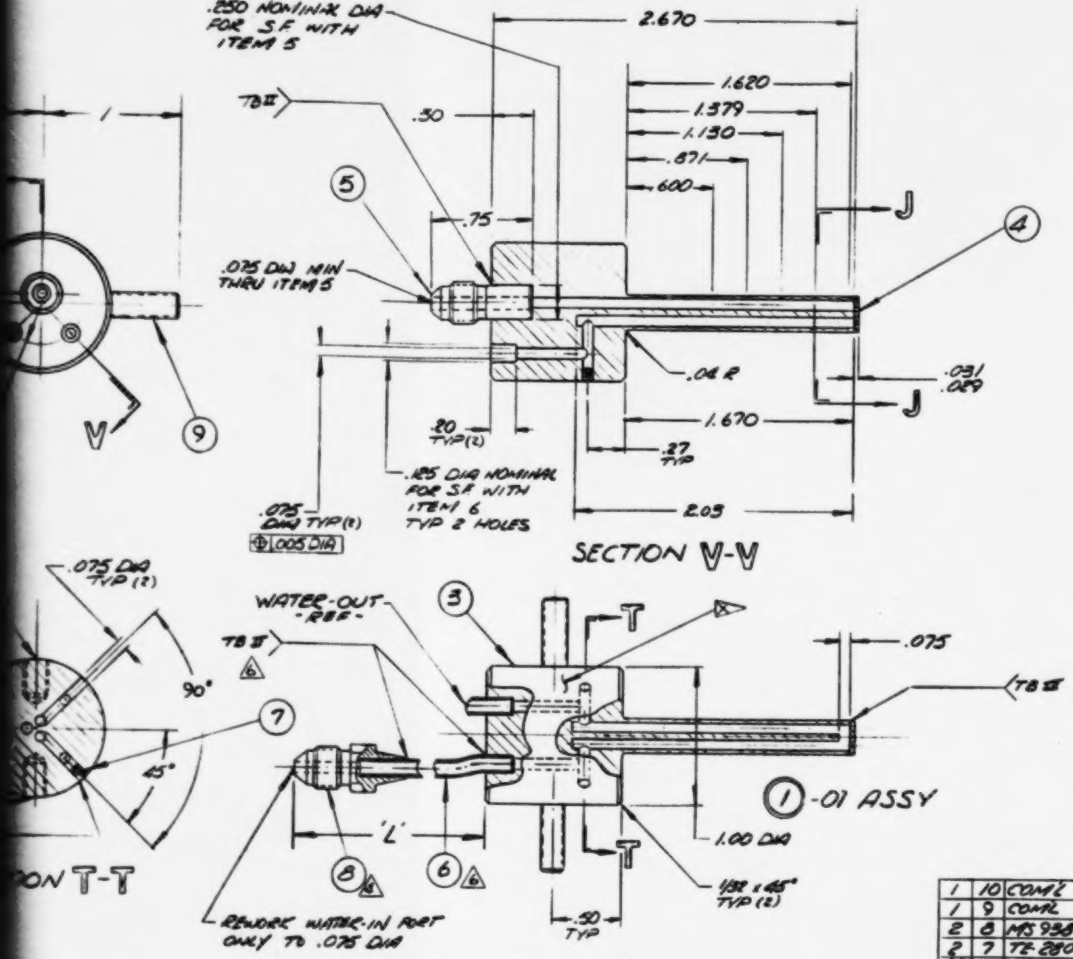

DO NOT SCALE DRAWING
.018-.020 DIA TYP 5 HOLES
.002 DIA
LEAVE EDGES SHARP
32
.251 .249 DIA
30° TYP
.062 RAD BSC
SECTION J-J
SCALE 10:1
.074-.076 DIA TYP 3 HOLES
.005 DIA
1
1
V
V
10
9
.300 RAD BSC
.250 NOMINAL DIA FOR S.F. WITH ITEM 5
TB II
.50
5
.75
.075 DIA MIN THRU ITEM 5
.20 TYP(2)
.125 DIA NOMINAL FOR S.F. WITH ITEM 6 TYP 2 HOLES
.075 DIA TYP(2)
.005 DIA
10-32 UNF-2B x .25 DEEP STAKE 3 PLACES AT ASSY FOR LOCKING.
.075 DIA TYP (2)
90°
45°
7
8-32 UNF-2B x .25 DP STAKE 3 PLACES AT ASSY FOR LOCKING
TB II TYP(2)
SECTION T-T
WATER-OUT -REF-
3
TB II
6
'L'
8
6
REWORK WATER-IN PORT ONLY TO .075 DIA
TABULAR DIM.
ASSY NO. | DIM 'L'
-01 | 2.00
7 PRESSURE TEST WATER LINE AT 50 PSIG
6 TUBE LENGTH SPECIFIED PER INSTALLATION. SEE TABLE
5 MFR. BY E.D.M. ONLY
4 MAY BE MADE FROM 1/8 TUBE SIZE FLARE FTG - CRES
3 MAKE FROM 1/8 TUBE SIZE FLARE FITTING - CRES
2 MATL: ANY AVAILABLE 300 SERIES CRES.
1 THIS DRAWING SUPERSEDES PSK 18696
NOTES:
APPLICATION

Figure 8-5. Individual Gas Sample Probe - Rig Style Print - TE28010-01

Preceding page blank

DO NOT SCALE DRAWING

REVISIONS					
E.O.	ZONE	LTR	DESCRIPTION	DATE	APPROVED



.250 NOMINAL DIA FOR S.F. WITH ITEM 5
2.670
1.620
1.379
1.130
.871
.600
.30
TB II
⑤
.75
J
④
.075 DIA MIN THRU ITEM 5
.04 R
.031
.029
J
1.670
.20 TYP(2)
.27 TYP
.125 DIA NOMINAL FOR S.F. WITH ITEM 6 TYP 2 HOLES
.075 DIA TYP(2)
⊕ .005 DIA
2.03
1
V
⑨
SECTION V-V
.075 DIA TYP (2)
90°
45°
⑦
ON T-T
WATER-OUT -REF-
TB II
③
T
.075
TB II
'L'
⑧
⑥
T
1.00 DIA
1/32 x 45° TYP (2)
.50 TYP
① -01 ASSY
REWORK WATER-IN PORT ONLY TO .075 DIA

TABULAR DIM.	
ASSY NO.	DIM 'L'
-01	2.00

AT 50 PSIG

INSTALLATION.

SIZE FLARE FTG - CRES

FLARE FITTING - CRES

SERIES CRES.

PSK 18696

1	10	COM'L	SETSCREW 8-32 x 3/16 LG	CRES	
1	9	COM'L	SETSCREW 10-32 x 3/16 LG	CRES	
2	8	MS 9381-02	COUPLING, TUBE	△	
2	7	TE-28010-07	PLUG .075 DIA x 3/32 LG	△	
A/R	6	TE-28010-06	TUBE 1/8 OD x .020 W	△ △6	
1	5	TE-28010-05	FITTING (1/8 TUBE)	△	
1	4	TE-28010-04	END CAP	△	
1	3	TE-28010-03	BODY	△	
	2				
☒	1	TE-28010-01	PROBE ASSY		
QTY REQD	ITEM NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL OR NOTE	ZONE

LIST OF MATERIAL

AVCO LYCOMING DIVISION

STRATFORD, CONNECTICUT

PROBE, GAS ANALYSIS ASSEMBLY

PASSIVATE

P6833

P6804

201

SEE 4/M

63

1

APPLICATION

SIZE	CODE IDENT NO.	
D	91547	TE-28010
SCALE 2/1	WT	SHEET 1 OF 1

TE-28010

- TE28010-01

8-10

is controlled by the main control panel, oven temperature control module, and electrometer module.

The main control panel provides the central location for power to the instrument, temperature control of the oven and detector and temperature monitoring of all thermal areas. An isothermal controller proportionally controls the oven at temperatures up to 400°C and is stable to ± .2°C of the set temperature. Conversion of the small current changes at the output of the ionization detector to a representative voltage is accomplished by the JFET (junction field effect transistor) electrometer. Range and attenuation are also selectable from this unit.

The FID detector consists of a flame-tip assembly attached to the detector base. Located above the flame tip is the collector (anode) electrode. The cathode probe which supplies the ionization voltage and ignitor coil is attached to the flame tip. Flame ignition is accomplished by applying a voltage to the ignitor coil.

Hydrogen (60 percent He Balance) is burned in an atmosphere of air (supplied HC free air). As the sample is introduced to the hydrogen flame through the base of the detector, the hydrocarbons are burned and, consequently, produce negative ions and electrons which are collected on the anode. The collection process produces an electrical current proportional to the burned material which is then amplified and converted to a readable voltage.

The purchased model 1400 was a standard injection-type gas chromatograph instrument requiring modification for continuous flow sampling. The injection column was removed, the carrier gas port plugged, and a two-position multiport, electric-operated stainless steel valve with flow restrictors was installed. The valve is located just upstream of the detector with sample, calibration, and bypass lines connected to the appropriate ports.

8.5.2 Chemiluminescent NO/NO_x Analyzer

The NO/NO_x analyzer is a Bechman 951H chemiluminescent analyzer. The instrument operating at a continuous flow through the detector analyzes either the NO or NO_x content of the sample.

In the NO mode of operation, a portion ($\approx$ 10%) of the nitric oxide is converted to electronically excited NO_2 by oxidation with molecular ozone. A photomultiplier detector senses the emission of photons and the NO_2 returns to the nonexcited state, thus generating a low-level signal.

The NO_x mode operates in a similar manner; however, before reacting with the ozone, the sample is routed through the converter to change NO_2 to NO. The resulting signals of the photomultiplier are amplified to drive the panel meter and external recording system.

The analyzer contains an internal bypass system for maximum response and pressure-dropping flow restrictors for pressurized sample inlet and atmospheric analysis.

8.5.3 CO/CO_2 Non-dispersive Infrared Analyzer (NDIR)

Two Horiba NDIR continuous-flow analyzers are used to measure the carbon monoxide and carbon dioxide concentrations contained in the sample. Models AIA-21-AS and AIA-21 were used for CO and CO_2, respectively. The cells are shock-mounted in the system to reduce pump vibration effects.

Both instruments operate on the principle of infrared (IR) absorbtion by the component of interest. A dual beam of collimated light passes through two parallel cells, one containing the sample and the other a nonabsorbing reference gas. A rotating optical chopper interupts the signals which are then directed to the detector where the difference in energy absorbed becomes a function of the concentration present in the sample. Sensitized detectors and an optical filter minimize interference from nonwanted components.

The AS-type detector used for carbon monoxide (in addition to its optical filters) uses a dual detector system to minimize water and CO_2 interference. The IR beam is passed through two detectors, the first of which contains the larger portion of the absorbed signal from the required component and the second the absorbed signal of the other components. The two signals are electrically subtracted by means of a mixing amplifier to produce a signal that is proportional only to the carbon monoxide content.

The sample cells are heated and temperature-controlled for stability and prevention of water condensation. The signals from both detectors are amplified and conditioned by separate electronic modules contained in a common chassis for meter display and auxiliary data system output.

8.5.4 Sample Flow System Description

Figure 8-6 is a schematic showing the flow path of the sample and calibration gases as they enter and pass through the system. A heated Metal Bellows pump (model 602) draws the sample from the probe at the rate of approximately 40-LPM and compresses the sample to 10 psi. A system bypass regulator maintains the pressure and bypasses the unused flow (20 LPM). A pressure gage and flow meter are used for continuous monitoring of the values. The remaining flow is split into three separate samples: 1) a THC sample, 2) a NO_x sample, and 3) a CO/CO_2 sample.

The THC sample (≈ 5 LPM) passes through a heated (150°C), sintered, stainless steel filter before entering the control valve in the FID oven. The sample pressure is dropped from 10 to 5 psi by a sintered stainless steel (FRIT) restrictor in the valve. A second FRIT restrictor, also in the valve, allows

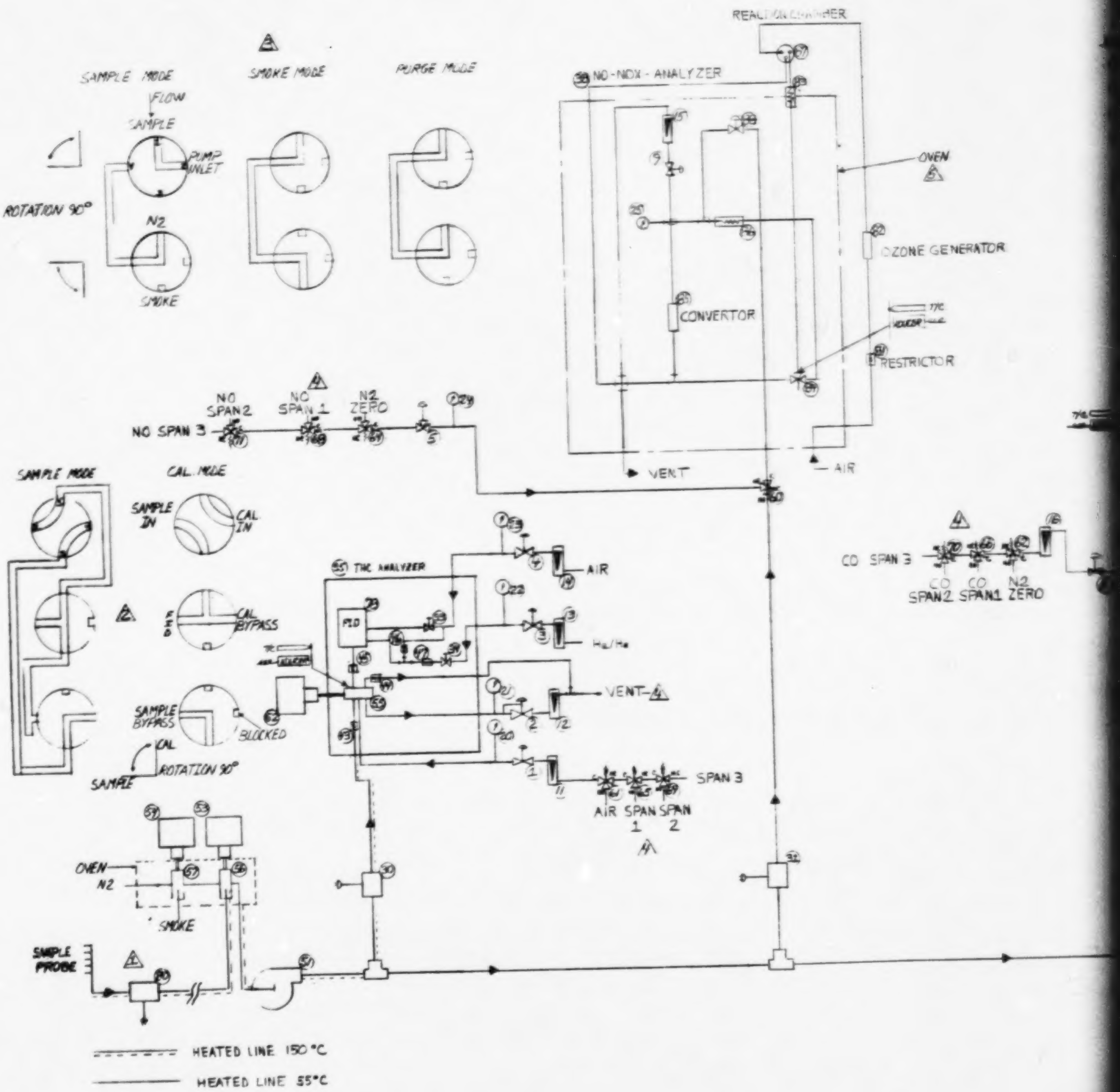
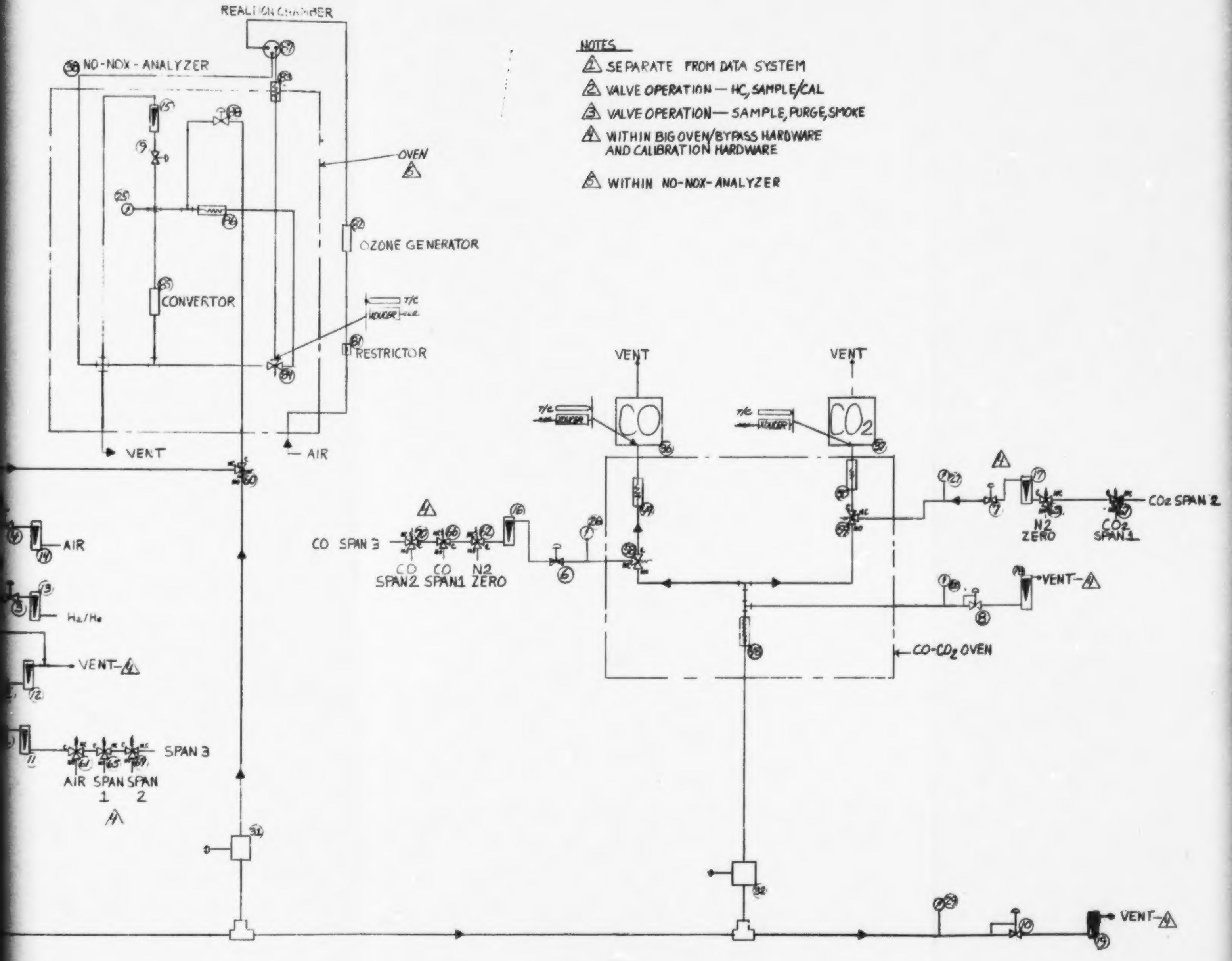

SAMPLE MODE
SMOKE MODE
PURGE MODE
FLOW
SAMPLE
PUMP INLET
ROTATION 90°
N2
SMOKE
NO-NOX - ANALYZER
OVEN
OZONE GENERATOR
CONVERTOR
RESTRICTOR
T/C
VENT
AIR
NO SPAN 3
NO SPAN 2
NO SPAN 1
N2 ZERO
SAMPLE MODE
CAL. MODE
SAMPLE IN
CAL IN
CAL BYPASS
SAMPLE BYPASS
BLOCKED
CAL
SAMPLE
ROTATION 90°
THC ANALYZER
FID
AIR
H₂/He
VENT
SPAN 3
AIR
SPAN 1
SPAN 2
CO SPAN 3
CO SPAN2
CO SPAN1
N2 ZERO
OVEN
N2
SMOKE
SAMPLE PROBE
HEATED LINE 150 °C
HEATED LINE 55°C

Figure 8-6. DS18 Emission Measurement Flow Schematic.


REACTION CHAMBER
NO-NOX-ANALYZER
OVEN
OZONE GENERATOR
CONVERTOR
RESTRICTOR
T/C
VENT
AIR
NOTES
1 SEPARATE FROM DATA SYSTEM
2 VALVE OPERATION — HC, SAMPLE/CAL
3 VALVE OPERATION — SAMPLE, PURGE, SMOKE
4 WITHIN BIG OVEN/BYPASS HARDWARE AND CALIBRATION HARDWARE
5 WITHIN NO-NOX-ANALYZER
VENT
VENT
CO
CO2
T/C
CO SPAN 3
CO SPAN2
CO SPAN1
N2 ZERO
CO-CO2 OVEN
CO2 SPAN 2
N2 ZERO
CO2 SPAN1
VENT
AIR
H2/He
VENT
SPAN 3
AIR
SPAN 1
SPAN 2
VENT

low Schematic.

approximately 18 cc/min. to enter the FID. The remaining flow is directed to the control oven where the HC bypass regulator maintains the 5 psi pressure at the sample restrictor, and the pressure and flow can be monitored.

The NO_x sample (approximately 2.5 LPM) is filtered by a second heated stainless steel filter and the pressure dropped to 7 psi by the NO_x regulator before entering the analyzer. A bypass regulator and flow meter built into the heated section of the instrument maintain an operating pressure of 4 psi and the bypass flow at 2 LPM.

The CO/CO_2 sample is filtered prior to entering the CO/CO_2 oven. In the oven, a FRIT restrictor drops the pressure from 10 to 5 psi while passing a total flow of 9 LPM which, in turn, is split three ways. FRIT restrictors at the input of the CO and CO_2 cells flow 2 LPM each and drop the pressure to just above ambient. The remaining 5 LPM is directed to the control oven where the regulator, pressure gage, and flow meter control and allow monitoring of the conditions.

All instrument exhaust (except HC) and bypass flows are vented from the rear of the control oven and pass through small jars before venting to the atmosphere. The moisture condenses in the jars and not the vent lines which would cause unwanted back pressure to the analyzers.

Two electrically operated valves at the input of the system can be selected to either allow the sample to enter the pump and through the system as described above or to be redirected to the DS16C smoke sampling system described in paragraph 8.7. A third mode of operation (N_2 purge) permits nitrogen gas to back-flow the sample line and probe to prevent fuel contamination during the start-up or shutdown cycle.

8.5.5 Calibration Flow System Description

The zero and span gases are input to the system at the rear of the control oven. Up to three span gases for THC, CO, and NO_x and two for CO_2 and zero gas for each can be input. Solenoid valves in the control oven, operated from a switch panel, direct the zero or span gases to each instrument as required. The SAMPLE/CAL solenoid valves at the input of each instrument, also controlled from the switch panel, allow independent instrument calibration selection.

Pressure regulators in the control oven for each set of calibration gases maintain a pressure level consistent with sample pressures under operating conditions. Flow meters and pressure gages are provided to assure consistent unrestricted operation.

8.5.6 System Temperature Control

Each instrument has self-contained heating elements and control circuitry. The THC instrument controller maintains the FID oven at 160°C and the detector base at 210°C. The NO_x analyzer is heated to 60°C and both the CO and CO_2 cells at 55°C. The three sample filters also contain independent heating elements and control units.

All system components contain heating elements, such as bar and finned heaters for the ovens and pump and nickel chromium wire for sample lines, which are controlled by five separate temperature control units. A thermistor-coupled feed-back circuit with current limit and temperature set point is used.

The pump heads, Sample/Smoke/Surge valve and 150°C stainless steel sample line (Dekoron 2152-06, 3/8 electro-trace) to the THC analyzer use two of the controllers to maintain these devices at 150°C. Two other controllers maintain the control oven and CO/CO_2 oven at 55°C which in turn heat the solenoid valves, flow meters, gages, regulators, and stainless steel tubing contained within them. The 55°C stainless steel sample lines (Dekoron 2150-04, 1/4 electro-trace) which connect the control oven to the instruments and filters are controlled by the remaining controller.

A temperature selection and read-out system is used to monitor the thermocouples installed in the various devices for proper operating temperature. In addition, a scanning/indicating unit has been incorporated in the system to periodically check sample lines for open circuits. A light indication on any of the switch positions, which corresponds to a specific section of line, indicates an unheated area that can be easily traced without numerous temperature measurements.

8.5.7 Detector Flow-Variance Compensation

In addition to the front panel sample pressures and temperature monitoring equipment, electrical transducers have been provided. Strain gage-type pressure transducers and type "K" thermocouples are installed near the inlet of each detector. The pressure transducers are installed in a "cool" location for stability and connected to the inlets by means of small stainless steel tubing. The thermocouples are in the sample flow stream.

The THC and NO_x analyzers are extremely sensitive to flow variations and require compensation for any differences. The transducers measure the pressure just upstream of the sample flow restrictors in both analyzers for recording and correction later by the data reduction program.

During each 30-day calibration or when one of the restrictors is changed, the pressure is set at a number of different values and the corresponding responses of the instrument to a span gas at these pressures are recorded. Correction factors are developed for input to the data reduction program to compensate for any deviation between calibration and sample pressures recorded during test operation. This technique also alleviates the need for time-consuming precise system adjustments or loss of data from most regulation problems which may occur.

The CO and CO_2 detectors are not flow-sensitive; however, the transducers in these instruments provide recorded assurance that no data errors due to downstream blockage are present.

Thermocouples measure the sample temperature entering the detectors for recorded indications of sufficient and consistent values during calibration and sampling. The thermocouples are referenced to 32°F by an electronic reference junction before being input to the acquisition system.

8.5.8 Data Output

Three means of monitoring and recording the data output from the instruments are available with the system: 1) continuous plots 2) digital readout, and 3) voltage signals for automatic acquisition systems.

Two dual pen plotters continuously record the four instrument signals representing THC, CO, CO_2, and NO_x emission levels. The primary purpose of the plotters is to determine stability of the set condition before acquisition.

A voltmeter selector switch and range indicator permit access to the instrument outputs for manual recording without interruption of the automatic recording system. The range indicator identifies, at a glance, the range being used. This section is used to monitor the calibration repeatability and record test values for input to a computing calculator for correlation of measured and computed fuel-air ratio.

The primary data acquisition is made using the DS8 Portable Digital Data Acquisition System discussed in paragraph 8.6. A total of sixteen values are output by the system for recording four values for each instrument. Signals are output from each instrument representative of the emission levels. Range signals of 1, 2, 3, or 4 volts are output by each instrument depending on the selected range. The data reduction program uses the range information for the proper selection of calibration, span gas, and instrument curve for use in computing the emission levels. The sample pressure transducer and thermocouple outputs of each instrument make up the remaining signals.

8.6 PORTABLE DIGITAL DATA ACQUISITION SYSTEM - DS8

This system was used in both the engine testing and combustion rig testing portions of the program to record the output from the DS18 emission measurement system.

This data system accepts, digitally converts, and records multiple inputs of pressure, temperature, and other types of voltage data. The voltages were derived from the gas analysis instrument outputs and the pressure sensor temperature monitoring thermocouples. The system is a mobile unit adaptable to all component and engine test areas, including the ones used for this program.

The signals are connected to an input scanner programmer. The scanner provides channel selection to the integrating digital voltmeter (via the amplifier) and external programming for the voltage range, sample period, and stabilization delay. Special control functions such as a pressure-scanner advance and actuator-position advance are also provided by the scanner.

The data system output is in two forms. The first is printed output available for examination by personnel at the test site, while the second output is a five-level IBM punched paper tape that is converted to a card form output for input into the main data reduction programs.

8.7 PORTABLE SMOKE MEASUREMENT DATA SYSTEM - DS16C

This system, shown schematically in Figure 8-7, uses the soiled-paper technique of collecting smoke particles to determine the smoke number present in the engine exhaust. The systems portability allows its use in any of the engine or combustor test areas.

The equipment and techniques conform to EPA standard 40 CFR, Part 87. As indicated, the sampling equipment is a self-contained unit with all the necessary control, pressure, temperature, and flow-measuring instruments. The sample is maintained above the dew point temperature to prevent water condensation.

The exhaust gas is sampled through the probe and passed through the filter paper (Whatman No. 4) producing a dark circular spot proportional to the smoke concentration in the gas. The spot is then measured for reflected light and compared with standard reflection values to determine the smoke number.

The spot reflection is determined by use of a Macbeth reflection densitometer, Model RD-400, which is a digital-readout, reflection densitometer equipped with four selectable filters for color and visual density measurements from 0 to 2.5 density units. The digital readout displays numerically to the hundreth of a unit and holds each reading in the display until the next measurement is made.

8.8 EMISSION MEASUREMENT TECHNIQUES

8.8.1 Background and Compliance

Many approaches to measure gas turbine emissions have been used by various manufacturers to satisfy individual requirements. The need for improvements in emission instruments technology and measurement techniques has long been realized by Lycoming and attempts to contribute to their advancement continued with this program.

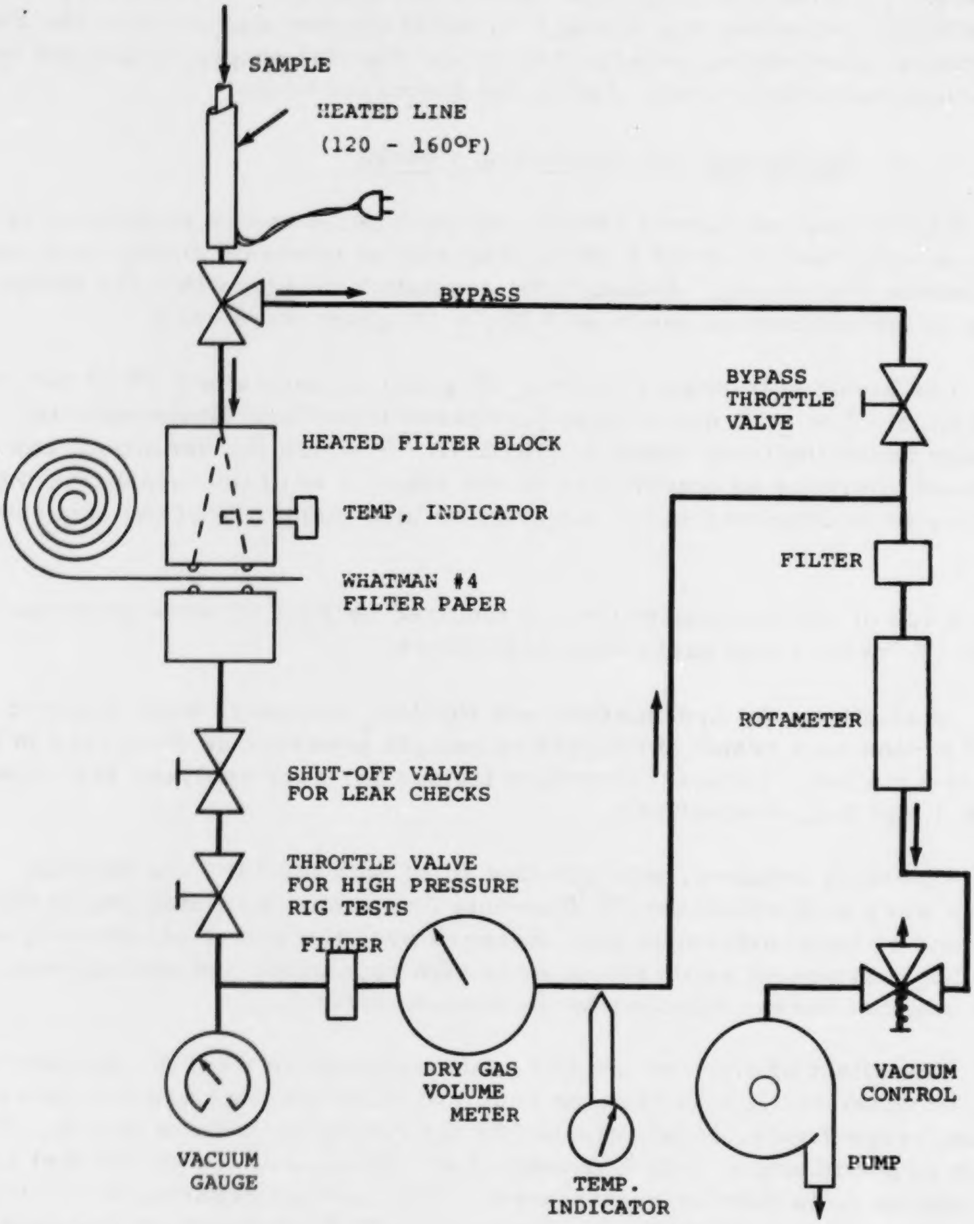

SAMPLE
HEATED LINE
(120 - 160°F)
BYPASS
BYPASS
THROTTLE
VALVE
HEATED FILTER BLOCK
TEMP, INDICATOR
FILTER
WHATMAN #4
FILTER PAPER
ROTAMETER
SHUT-OFF VALVE
FOR LEAK CHECKS
THROTTLE VALVE
FOR HIGH PRESSURE
RIG TESTS
FILTER
DRY GAS
VOLUME
METER
VACUUM
CONTROL
VACUUM
GAUGE
TEMP.
INDICATOR
PUMP

Figure 8-7. DS16C Portable Smoke Measurement System-Schematic.

The procedures for emissions test were established by the EPA and published in the Federal Register on 17 July 1973. These procedures were used in the majority during this program. Where deviations were necessary, specifically for combustor rig testing, a formal request was made to the EPA. The techniques used during both the engine and rig test programs and the results of the various emission system checks are discussed below.

8.8.2 Calibration and Instrument Checks

The 30-day instrument checks and calibrations were performed in accordance with Part 87 of the Federal Register at intervals during both engine and combustor rig testing. Although the regulation requires that the analytical accuracy of the calibration gases be ± 2%, ± 1% gases were used.

The blending tolerance of the ± 2% gases is normally ± 5% of the requested concentration. The ± 1% gases were purchased from Scott Environmental Technology under the trade name ACUBLEND TM which (by definition) has a "zero" blend tolerance as determined by the sensitivity of the measuring instrument. The bottles were delivered in the majority as less than 1.5% of the requested value.

Each of the instrument checks required by Part 87 were performed using the 1% "zero" blend gases described above.

In addition, the hydrocarbon and NO/NO_x analyzers were checked for output variation as a result of changes in sample pressure as discussed in the system description. Typical correction factors for each analyzer are shown in Tables 8-1 and 8-2, respectively.

The least-squares, straight-line fit of both the THC and NO/NO_x analyzers were well within the 2% allowable deviation. Repeatability in the calibrations of each instrument was observed over the period of this program. The CO and CO_2 instrument calibrations were also repeatable and also agreed closely with the original curves supplied by the manufacturer.

The effect of different oxygen concentrations on the THC analyzer was found to be consistently less than the required three-percent and five percent deviation, respectively, of propane in 10% O_2 and N_2 to propane in AIR. The technique of premixing a small amount of air (20 ml/min.) with the fuel allows the instrument to satisfy the requirement. This method reported by K. Schofield(2) had previously been used satisfactorily on other FID analyzers at Lycoming.

---

(2) Problems with Flame Ionization Detectors in Automotive Exhaust Hydrocarbon Measurements, Keith Schofield, Environmental Science and Technology, Volume 8, Number 9, September 1974, PP. 826-834

TABLE 8-1. HYDROCARBON ANALYZER PRESSURE CORRECTION FACTORS

FID Sample Pressure (1)	HC-Correction Factor (CF) (2)
21	1.552
22	1.422
23	1.326
24	1.238
25	1.150
26	1.088
27	1.022
27.3	1.0
28	0.961
29	0.9109
30	0.0619
31	0.8179

(1) The values listed are the millivolt output of the transducers. These values only represent pressure and are not indications of psia or psig; i.e., 27.3MV = 5 psi

(2) $CF = \frac{\text{Output @ } 27.3}{\text{Output @ } x}$ $x = 21, 31$

Tm,

TABLE 8-2. NO/NO_x ANALYZER PRESSURE CORRECTION FACTORS

FID Sample Pressure (1)	Correction Factor (CF) (2)
11.5	1.192
12.0	1.142
12.5	1.117
13.0	1.090
13.5	1.063
14.0	1.043
14.5	1.018
14.9	1.0
15.5	0.969
16.0	0.951
16.5	0.935
17.0	0.918

(1) The values listed are the millivolt output of the transducer. There values only represent pressure and are not indications of psia or psig; i.e., 14.9 MV = 4 psig

(2) $CF = \frac{\text{Output @ 14.9}}{\text{Out @ x}}$ x = 11.5, 17

The CO analyzer water vapor and CO_2 interferences checks were made using nominal values of 5% and 4%, respectively. The standard bubble-jar technique of saturating nitrogen-zero gas was used. The error to both water vapor and CO_2 was consistently less than 1.5% on the lowest range (100 ppm).

In addition to the standard instrument checks, Lycoming subscribes to the Scott Cross-Reference Service. The service provides a convenient means of checking instrument performance, calibration procedures, and comparative accuracy to others analysis. A bottle of gas supplied by Scott Environmental Technology contains an unknown concentration of propane, CO,and CO_2 to be analyzed. The results are returned to Scott where the data from each subscriber are tabulated, statistically analyzed, and issued as reports. The results of those bottles analyzed during the contract period are shown in Table 8-3.

8.8.3 Daily Pre-Test Checks

8.8.3.1 Instrument Operation Checks and Adjustments - After the instrument and system warmup time, each instrument was checked for response to each zero and span gas and compared with the previous day's calibration. Adjustments were made if found to be necessary. At no other time during the day's test were the electrical zero and spans adjusted. Experience with the instruments indicates a significantly greater stability if unchanged.

8.8.3.2 Clean Line and Pressure Check - A check of the sample line for contamination was performed prior to and following each engine test cycle and rig-test day. Clean filters were installed. Zero air and a propane span gas were alternately input to the probe-end of the sample line, and the response of the THC analyzer was compared with the known value. Deviations of more than 2 percent were not observed. The regulation indicates a check of the sample line condition be performed with each hourly calibration. A deviation from the procedure was requested and granted by the EPA. It was indicated that the sample line reaches an equalibrium condition at each point and to introduce zero and span gas would unnecessarily disturb this condition. Depending on the levels of emissions, a considerable length of time could be required to achieve a legitimate zero. Restabilization of the line to the sample condition is then required before the point can be recorded.

The line was also checked for smoke contamination by taking a sample with the probe connected. Twenty liters were drawn through the filter paper at normal operating pressures and temperatures.

To pressure check the sample line from the probe to the system, the line was capped and the system switched to N_2 purge. The N_2 bottle valve was turned off, and a drop-off in pressure, as shown by the gage, indicated any possible leak. The data system was not pressure-checked since it operates

TABLE 8-3. 1976-DIESEL CROSS-REFERENCE SERVICE(1) ANALYSIS

Report No.	Avg (No. Data)	Median	Est of STD Deviation	Est of STD Error	Avco Lycoming (CT)	
					DS18	Scott GC
1						
HC (PPm)(2)	177.2 (12)	177	± 2.82	± 0.813	179.4	177.3
CO (PPm)	529.8 (14)	535.5	± 20.1	± 5.38	507	512
CO_2 (%)	3.107 (13)	3.1	± 0.0653	± 0.0181	3.09	3.15
2						
HC (PP m)	676.5 (11)	675.0	± 8.36	± 2.52	665.4	681
CO (PP m)	168.7 (13)	167.0	± 9.95	± 2.76	155.7	160
CO_2(%)	8.258	8.17	± 0.289	± 0.0802	8.69	8.26
3						
HC	30.35 (10)	30.25	± 1.26	± 0.399	30.59	30.07
CO	10,162 (12)	10,200	± 222.2	± 64.1	— (3)	10,200
CO_2	1.86 (13)	1.88	± 0.084	± 0.023	1.95	1.86
4						
HC	857.1 (15)	844.0	± 53.95	± 13.93	834.2	846
CO	1009 (18)	1001.	± 28.2	± 6.64	1018	1022
CO_2	5.92 (16)	5.93	± 0.079	± .020	5.96	6.038

1. Scott Specialty Gases, a Division of Scott Environmental Technology Inc.
2. Hydrocrabons as Methane
3. Beyond Range of Instrument

above atmosphere from the pump output to the input of each instrument.

8.8.3.3 NO_x Efficiency Test - The efficiency of the converter used to change NO_2 to NO in the analyzer was checked each test day. The tester was built and used in accordance with the description and procedures specified in the regulation. Efficiencies greater than 95 percent were common, and no values were ever below the 90 percent requirement

8.8.3.4 Residence Time Check - Figure 8-8 is a schematic of the residence time check setup. A three-way selector valve with two throttle valves attached was connected to the end of the sample line. With the system pump on, the two throttling valves were adjusted to achieve test operating pressures and flows at the system equally from both directions through the selector valve.

After injecting a generous quantity of either propane, CO, CO_2, or NO into the 283-liter (10 $ft.^3$) mylar bag, the bag was connected to one side of the selector valve. The selector valve was then quickly switched from the atmosphere side to permit the system to draw the sample from the sample bag.

The output of the appropriate instrument was recorded on the strip-chart recorder operating at one second per inch . The system operator marked the plot at the point the valve was switched. The test was repeated three times to obtain a representative average. The response times for the engine and combustor rig tests were: CO - 6.0 sec., CO_2 - 3.6 sec., HC - 10 sec., and NO_x - 5.9 sec.

The sample transfer time from the probe to the system was calculated and found to be about 1.5 seconds for both the engine and rig test.

8.9 SENSORS AND PROBES FOR AEROTHERMODYNAMIC DATA

Measurement of the operational control parameters and inlet conditions was made with specially designed probes and sensors, which were developed over many hundreds of hours of engine and rig testing. Recording of engine test data values was accomplished by the use of an IBM 1800 computer-based, data-acquisition and computation system. Combustor rig test data were recorded using a Lycoming-designed digital data acquisition system.

Total pressures were sensed using averaging impact type rakes. Static pressures were measured with sharp-edged ports on duct walls. Liquid flows were measured with precalibrated turbine-element flowmeters. Temperatures were measured with I.C. or C.A. thermocouples, both shielded and unshielded, depending on application. Calibration of the wire used conformed to NBS standards, for $\pm 4^\circ F$ measurements.

Humidity in the combustor rig testing was measured by withdrawing a sample of the air at the inlet to the rig by means of a single-point total-impact probe inserted 15 centimeters into the airstream.

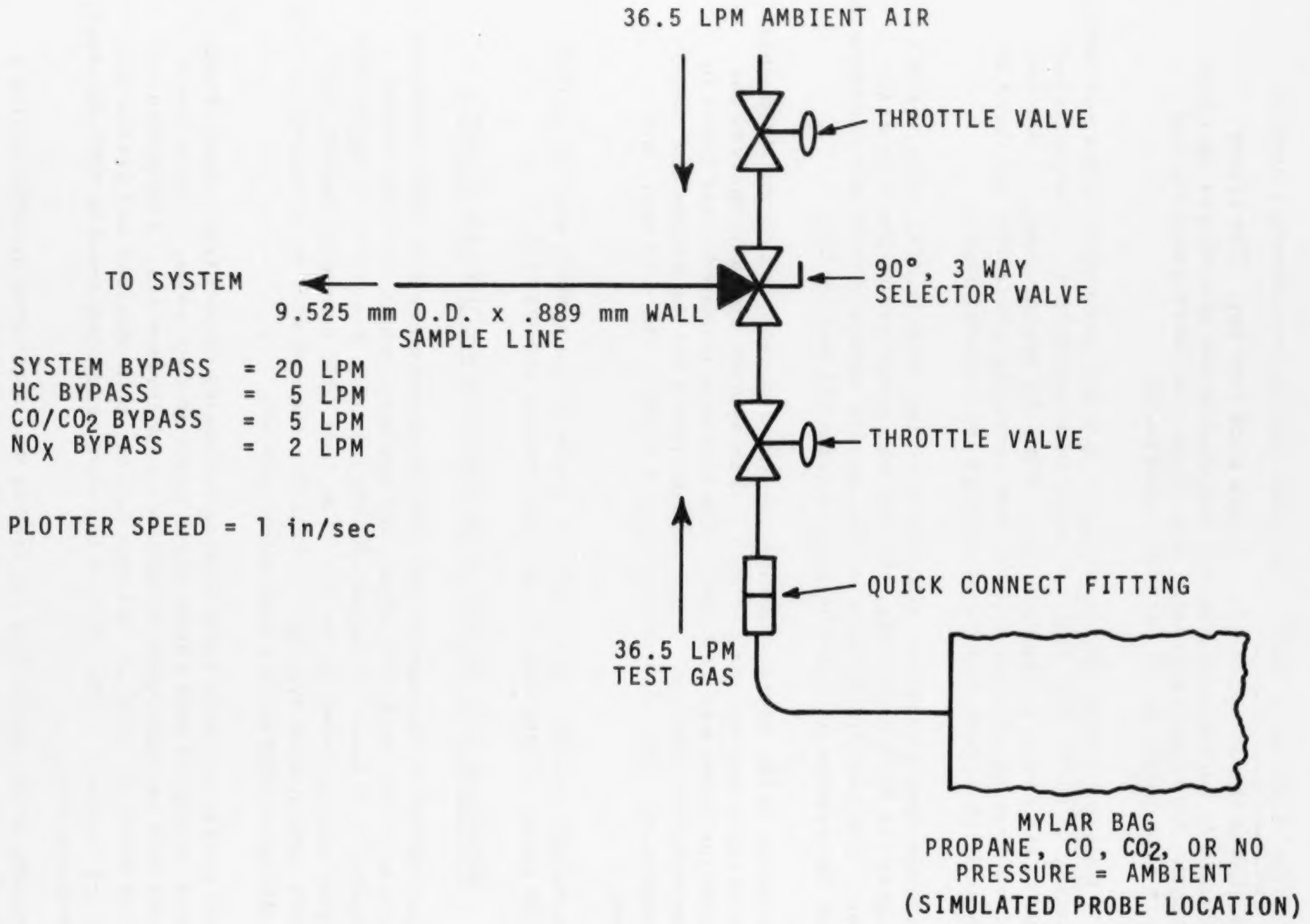

36.5 LPM AMBIENT AIR
THROTTLE VALVE
TO SYSTEM
90°, 3 WAY SELECTOR VALVE
9.525 mm O.D. x .889 mm WALL SAMPLE LINE
SYSTEM BYPASS = 20 LPM
HC BYPASS = 5 LPM
CO/CO_2 BYPASS = 5 LPM
NO_x BYPASS = 2 LPM
THROTTLE VALVE
PLOTTER SPEED = 1 in/sec
QUICK CONNECT FITTING
36.5 LPM TEST GAS
MYLAR BAG
PROPANE, CO, CO_2, OR NO
PRESSURE = AMBIENT
(SIMULATED PROBE LOCATION)

Figure 8-8. Residence Time Check Schematic.

The humidity distribution was investigated at selected conditions prior to the test program by traversing the combustor inlet dewpoint sample probe across the channel and noting the change. With the water spray nozzles located some 12 meters upstream and two 90-degree turns in the piping system, no deviation was expected or observed.

8.10 MULTIPLE INPUT DIGITAL DATA ACQUISITION SYSTEM - DS10

This data acquisition system was used during the combustor rig testing to record all data other than emissions measurements.

The system accepts, digitally converts, and records multiple inputs of pressure, temperature, and other voltage data by means of an integrating digital voltmeter. The inputs were derived from sensors connected to various locations on the combustor development test rig. The system has the capacity to read 200 independent signals from any of the test cells located in Lycoming's Building 19 complex.

The combustor configuration can use part of the 200 input signals in the following manner: one absolute pressure transducer scanned through 48 pressure ports; two differential pressure transducers (up to ± 25 psid) each scanned through 24 pressure port pairs; and two frequency (fuel flow) signals. The remainder of the input signal recording capability is used for thermocouples of other miscellaneous signals.

The transducers are installed in a temperature-controlled cabinet consisting of one absolute scanner with a 48-port scanning capability, and two differential scanners with 24 ports each. The cabinet is located near a valve panel and connected to the common of each valve by plastic tubing. The valve selector system permits easy and fast turnaround time to one of the five test areas. Pressure ranges up to 200 psia are acceptable for such a system, although 150 psia is the normal working limit.

Pressure transducer calibration is accomplished by selected, known high-quality (± .02%) pressures as part of scanned data. In this manner, a multipoint calibration curve is recorded for each data point and is used in computer program correction techniques. Repeatability of better than ± .002 psi of pressures less than 30 psia are generally achieved. For pressures higher than 30 psia, ± .01 psi repeatability is generally possible.

The differential pressure scanners are used for accurate measurement of differential pressures. Calibration pressures, normally 0 and 2 psi, are input to the first two ports of the scanner and recorded by the data system to permit computer correction routine calculations. Individual signal conditioning to obtain the desired output voltage for the corresponding calibration pressure is also used for these transducers. Accuracy of better than ± 0.1% is achieved while repeatability is found to be less than ± .002 psi.

Thermocouple cold-junction compensation is accomplished through a 36-point, 32°F electronic reference junction. A series of thermocouple jack panels allows any of the five combustor testways to be selected. Reference junction cycling and validity are checked by a precision 150°F signal source which is recorded with every data scan.

The data system's output is in two forms. The first form is printed output for examination by engineering personnel at the test site. The second output is five-level, I. B. M.-punched paper tape for later conversion and input into data reduction computer programs. An additional feature of the system is the ability to have the output printed automatically in engineering units (psia psid, °F, and rpm) to provide the engineering evaluation of the data before the normal data scan is taken.

8.11 ENGINE CELL DATA SYSTEM IBM 1800

The IBM 1800 system was used to record engine operational and ambient parameters during the engine-test portion of the program. Application of the IBM 1800 Data Acquisition and Control System (DACS) that supports test facility is discussed below.

Four test cells are presently being serviced, wherein each pair of cells is separated by a control room designed to direct the activities of the adjacent cells. Each control room is equipped with its own CRT unit for online monitoring and an alphanumeric keyboard for communication with the IBM 1800 DACS.

The IBM 1800 DACS provides for the continuous monitoring of gas turbine engines under test and the permanent recording of a family of engine parameters.

Test monitoring is achieved through the acquisition (scan), logical treatment, and CRT display of parameters having a response time goverened by time-dependent constraints and through the detection of critical conditions (alarm system) having an even faster response time.

Test data recording includes the acquisition, logical treatment, and output of all parameters instrumented for a given engine test. All defined conversion and performance calculation s are also output. Recording provides onsite printer and magnetic tape output with all parameters appropriately identified; this not only provides a permanent record of the test data for future reference, but also permits processing of the data by data reduction and engine cycle match-point performance programs on a host computer.

The acquisition system is equipped with a 32K memory, two 512K word discs, a magnetic tape unit, a card reader, and a punch and line printer.

As many as 300 variables can be acquired, computations made, and output supplied to the various devices for off-line analysis. The complete acquisition time to acquire the engine data occurs in approximately 15 seconds of initiation.

Selected variables were converted by the system to engineering units and used to compute the required parameters for the CRT update at the engine control station.

8.12 HUMIDITY MEASUREMENT

Humidity was measured by General Eastman (Model 1200 AP) dewpoint meters that work on the principle of condensation on a temperature-controlled mirror.

The series 1200 dewpoint hygrometers are thermoelectrically cooled, optically detected, automatically controlled, condensation (or dewpoint) hygrometers. The principle of operation is shown in Figure 8-9.

The condensate detection mirror is illuminated with a high-intensity, solid-state, light-emitting diode (LED). A photodetector is configured so as to monitor the specular (direct) component of the light from the mirror. A separate LED and photodetector combination are used to compensate for any thermally induced changes in the optical components. The photodetectors are arranged in an electrical bridge circuit such that the specular detector is fully illuminated when the mirror is clear of dew and sees reduced light as dew forms on the mirror, due to scattering losses.

An optical offset is designed into the bridge such that a large bridge output current is developed whenever the mirror is in the "dry" condition. The bridge output is amplified and used to control the direct current to the thermoelectric cooler, causing the mirror to cool toward the dewpoint. As dew begins to form on the mirror, the optical bridge is driven toward its balance point, causing a reduction in the specular light, causing the bridge output to decrease, and the cooling current to reduce. A rate feedback loop within the amplifier is employed to insure critical response, and the system quickly stabilizes at a condition wherein a thin dew or frost layer is maintained on the mirror surface, i.e., the dew or frost point. A precision thermometer-element is embedded within the mirror to monitor this dewpoint temperature directly.

The condensation hygrometer is a fundamental method for measuring water vapor, thereby affording a degree of accuracy not available with other methods. Additionally, the repeatability of the instrument can be checked at any time by opening the control loop and allowing the mirror to heat and the dew

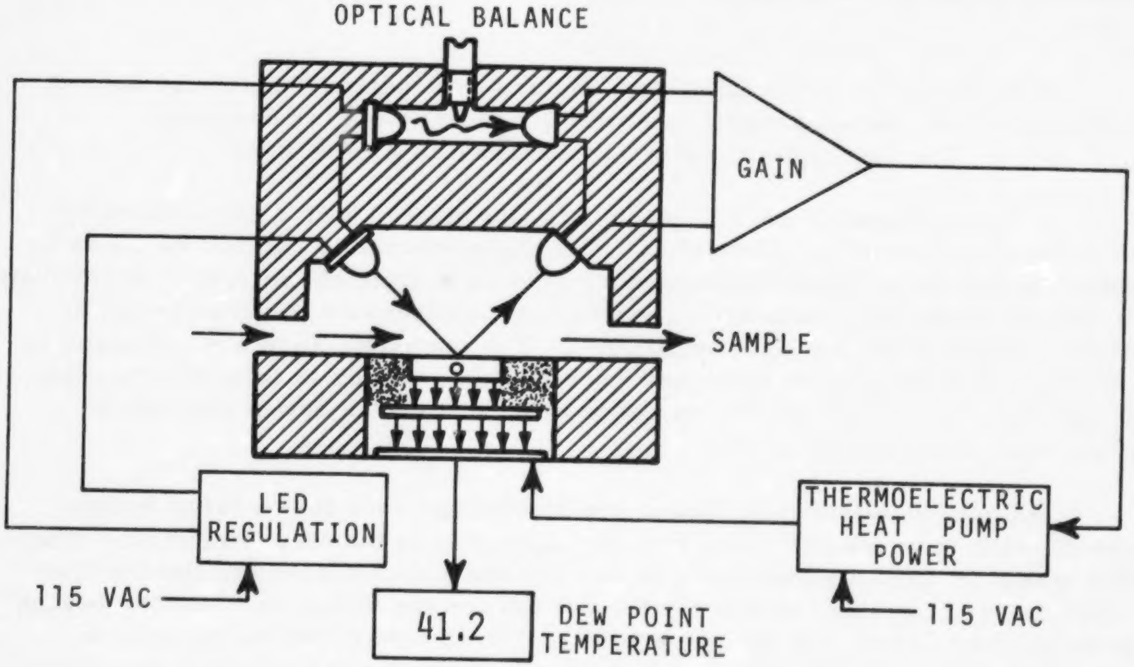

OPTICAL BALANCE
GAIN
SAMPLE
LED
REGULATION
THERMOELECTRIC
HEAT PUMP
POWER
115 VAC
41.2
DEW POINT
TEMPERATURE
115 VAC

Figure 8-9. Dew Point Meter Operational Schematic.

to evaporate, and then reclosing the control loop. Long-term accuracies in the order of ± 0.2°F are common with the condensation hygrometer, thus making it suitable as a laboratory reference instrument.

During the engine test program, the air samples were extracted from the test cell. During the rig-test program, samples were taken at two stations in the testway upstream of the combustor rig.

Upstream of the humidity-conditioning spray nozzle, a small sample of the air was extracted from the testway through a standard Kiel-type pressure probe. The probe was connected via a 6.35 mm (0.25 in.) O.D. stainless steel unheated but insulated line to a General Eastman (Model 1200AP) dewpoint sensor for measuring the incoming or ambient humidity. A similar probe at the combustor inlet was connected to a second sensor; however, this connecting line was heated to maintain the temperature above the dewpoint resulting from the added water.

Both sensors were mounted in the heated temperature-controlled box and maintained above the dewpoints. Line restrictions ahead of the sensors and placement of the sensors some 6 meters from the probes were used to control the pressure, temperature, and flow within the limits of the sensors.

The sensors were electrically connected to the dewpoint meters located in the control room. The meter provided digital readout for set-point operation. A secondary calculation of the dewpoint was also made using measured water flow through the conditioning spray nozzles and the moisture content in the ambient air. The water was measured with calibrated turbine-element flow meters. A comparison of the two measurement methods is presented in Section 11.3.

9.0 COMBUSTOR RIG TESTING

9.1 GENERAL

The combustor rig-test portion of the program was conducted on a full engine combustion system under controlled inlet conditions to obtain emissions data over a wide range of simulated engine environments. Tests were run in the idle to 1.5 times idle range and at approach conditions under actual engine conditions of temperature, pressure, and humidity. Twenty-two different environmental conditions were covered at each of the three power settings run. The high power conditions shown in Table 7-2 were not run.

Lycoming's ALF 502 combustor rig was used in the aerodynamic component test laboratory to accomplish this testing. The rig, laboratory facilities, and operating procedures are described in detail below.

9.2 COMBUSTOR TEST RIG

9.2.1 Rig Description

The Lycoming ALF 502 combustor component test rig provides a functional simulation of the engine flow conditions to allow determination of operational characteristics as they would occur in the full engine. The same rig has been used for the development tests of the combustion systems for Lycoming's T55 and ALF 502 engine families.

The combustor test rig shown installed in the testway in Figure 9-1 consisted of the engine combustor liner, housing, fuel manifold assembly, and the inlet/exit transition sections. A modified compressor diffuser, combustor outer curl, and instrument drum are mounted to the inlet duct as shown in Figure 9-2.

The exit-plane instrument drum on which the gas sample probes are mounted is connected to a centershaft through which the sample gas flow, cooling fluid, and cooling air are fed.

The combustor liner housing, and fuel manifold assembly with flow divider mount to the inlet flange. The inner curl mounted to the water-jacketed exhaust section and exit transition duct complete the flow path and assembly.

The rig is designed to accept engine hardware without modification and operate at pressure levels up to 10 atmospheres with maximum inlet and exhaust temperatures of 315°C (600°F) and 1200°C (2200°F), respectively; this allows direct simulation of combustor inlet conditions for idle, 1.5 idle, and approach modes. The rig also includes the instrumentation necessary to define the inlet and exit operating parameters.

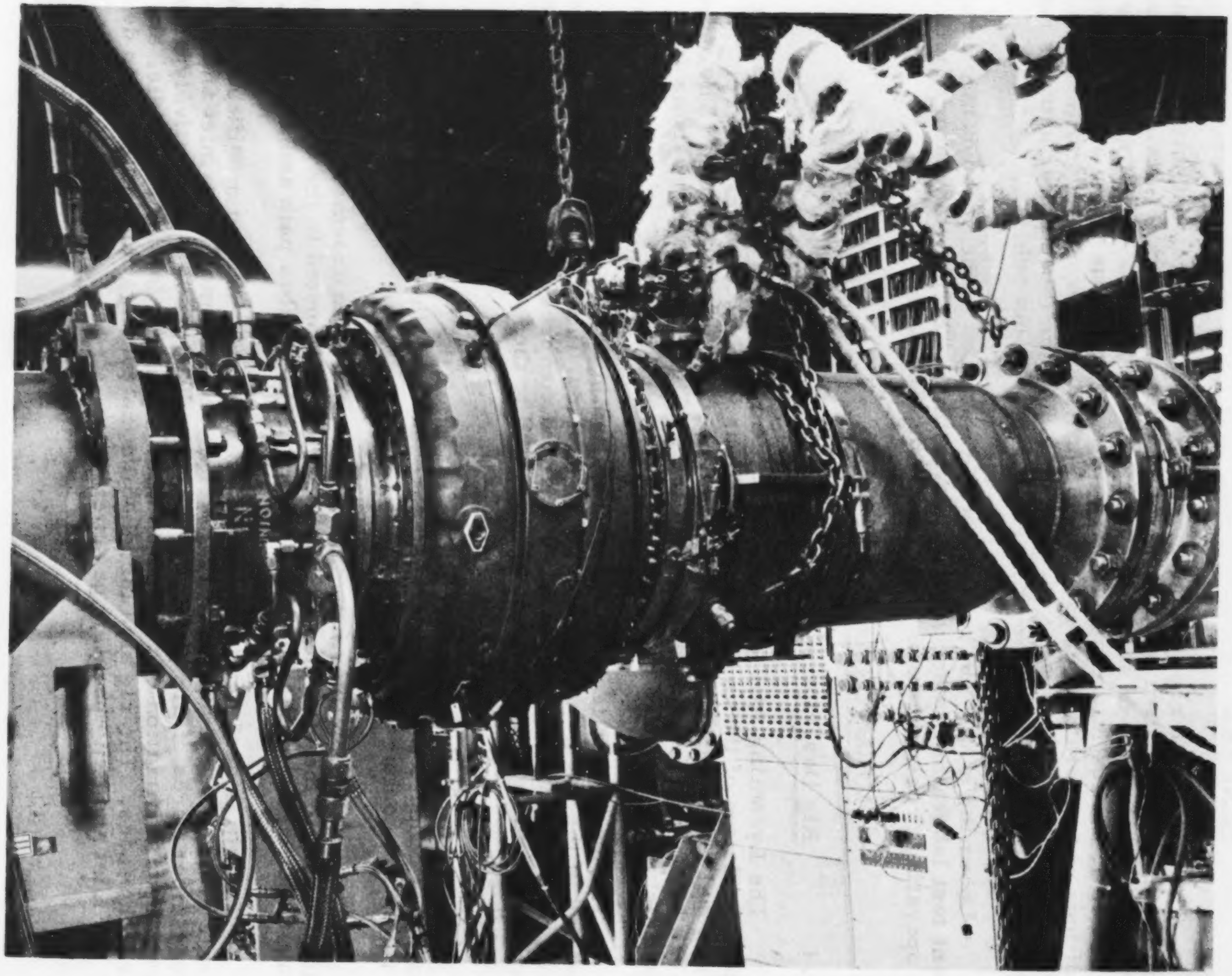


Figure 9-1. ALF 502 Combustor Test Rig Installation.

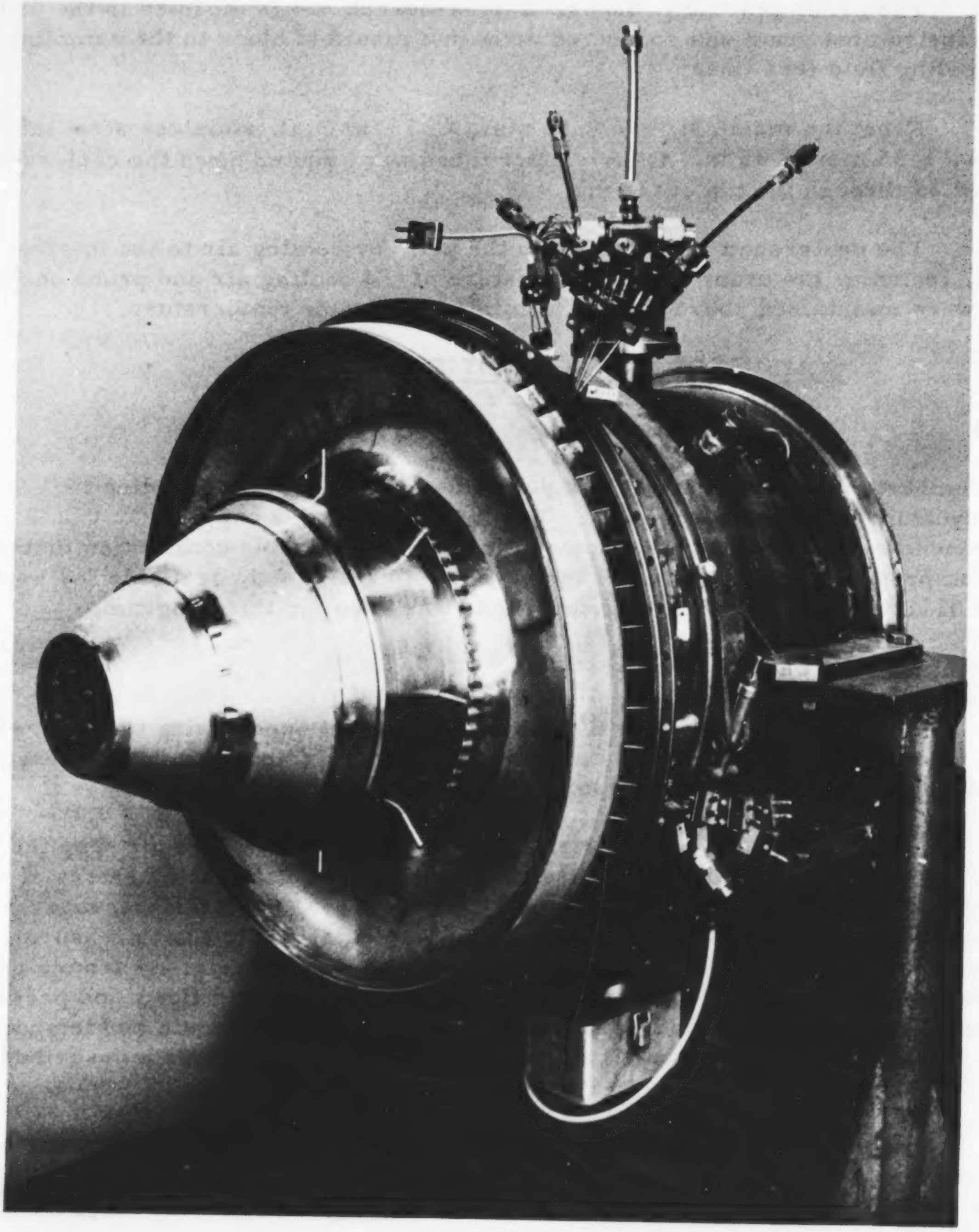


Figure 9-2. Combustor Rig Assembly - Partial.

9.2.2 Rig Gas Sampling System

The probe assembly discussed in paragraph 8.4 is mounted in the exit plane instrument drum and connected through a manifold block to the sampling and cooling fluid feed lines.

From the manifold, one 9.53 mm (0.375 in) O.D. stainless steel tube and two 6.35 mm (0.25 in.) O.D. copper tubes were routed down the centershaft and exited through the top of the rig.

The centershaft also serves as the path for cooling air to the internal rig parts, including the drum. The temperature of the cooling air and probe cooling fluid were maintained above the 150°C minimum sample temperature.

9.3 COMBUSTOR TEST FACILITIES

9.3.1 General

The combustor rig test (Task I) was performed in Lycoming's Building 19 Aerodynamic Laboratory complex . This area is used for engine component evaluations and development programs, including combustion,turbine and compressor systems. One of the seven testways (TW-1) available for various types of combustor and operating conditions was used for this program.

9.3.2 Air Supply

Two different pieces of air-moving equipment used during this test were: 1) an electric motor-driven industrial style compressor and 2) a multiple engine-driven T55-L-11 engine compressor.

The Allis-Chalmers industrial style centrifugal compressor supplies 10 lb/sec of air at up to 3 atmospheres and with the aid of electric heaters at temperatures between 93°C (200°F) and 315°C (600°F). Constant pressure control (±.02 psi) is accomplished by automatic sensing of rig inlet pressure acting to control the main compressor exit valve. The source of air from a gas turbine engine-driven T55 compressor was used for the higher flows and pressure levels. This facility presently provides 21 lb/sec of air at 96 psia and temperatures up to 315°C (600°F). The same pressure control system previously described is used.

Shop air or air extracted from the T55-L11 compressor, depending on rig pressure level,is supplied at approximately 0.5 lb/sec to the rig for cooling of the combustors internal components. This air was also passed through a bank of electric heaters for temperature control.

9.3.3 Rig Air Humidification System

To achieve the humidification requirements for this program, it was necessary to provide a means of injecting water into the inlet air and measuring the resulting humidity. An available pressurized water source was used to supply a spray-manifold installed upstream of the combustor.

The high-pressure water (up to 500 psi) was filtered and supplied to the water-spray manifold (Figure 9-3) through a series of three fluid-measuring turbine elements (0-50, 0-500, and 0-5000 lb/hr). These manifolded elements were remotely selected and the flow controlled from the control room.

The water-spray manifold located some 12 meters from the combustor inlet consisted of four nozzles of the type shown in Figure 9-4. Three of the nozzles were sized for a maximum water flow of 600 lb/hr and one for 200 lb/hr maximum.

Individual shutoff valves provide selection of any combination of the nozzles for sufficient flow and control. The nozzles were specifically designed and built at Lycoming to achieve the insertion depth and control required for this application.

9.3.4 Fuel System

Jet A fuel was supplied by the main plant farm fuel tanks to the Building 19 fuel distribution and control system.

The fuel was fed to the combustor by the pumping and control system using a positive-displacement pump and pneumatically controlled metering valves. A fuel-element manifold consisting of 0-50, 0-500, and 0-5000 lb/hr turbine elements, selectable from the control room, was used for all fuel measurements. The element output was displayed at the operation console and recorded on the digital data acquisition system for later data reduction.

Before entering the combustor, two steam heat exchangers were used to control the temperature of the fuel at a level comparable with those found during engine testing (Task II). Steam flow to the heat exchangers was pneumatically controlled from the control room.

9.3.5 Gas Sample Probe Cooling

Emissions measurements are generally more difficult in combustor rig tests than in an engine test. The severity of the conditions experienced by the gas sample probes, sometimes in excess of 1100°C during operation, required that cooling techniques be implemented.

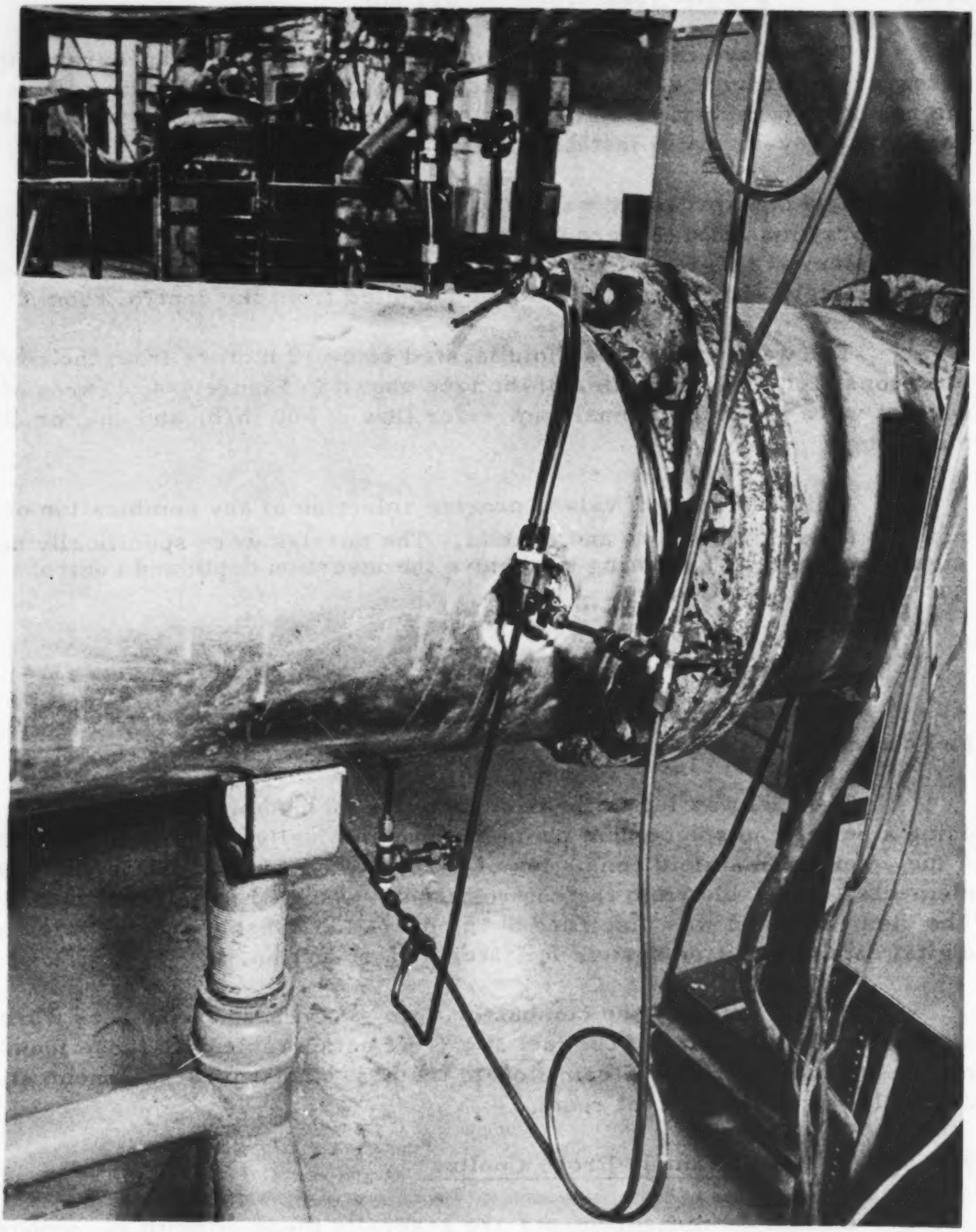


Figure 9-3. Water Spray Installation.

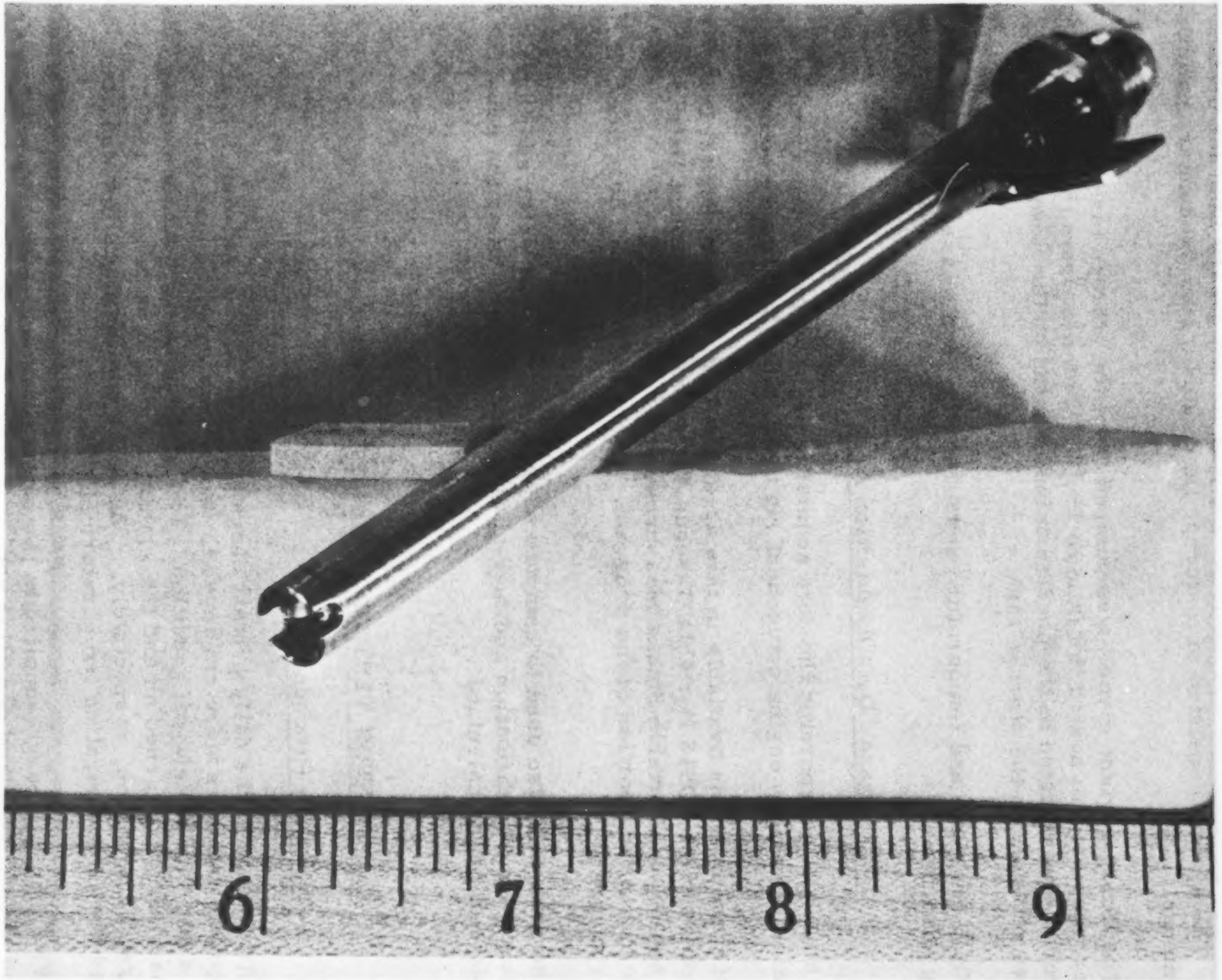


Figure 9-4 Water Spray Nozzle.

A portable, fluid heating stand commonly used for many experimental engine and component tests was adapted to supply the necessary fluid for probe cooling. The system consisted of a storage tank, steam heat exchanger, pump, and flowmeter.

The fluid (ethylene glycol) was pumped from the storage tank to the heat exchanger where steam heated the fluid to 150°C. The flow from the exchanger to the probes was adjusted to the predetermined setting on the flowmeter and the excess returned to the storage tank.

Fluid pressure and temperature sensors were used to assess and control operating conditions.

9.3.6 Performance Data Acquisition Area

This area incorporates the data acquisition system used for performance investigation of various engine component rig tests in the Building 19 complex.

Of these systems available in this area, the DS8 and DS10 Digital Data Acquisition Systems, DS18 Portable Gaseous Emission Measurement Data System, and DS16C Portable Smoke Measurement System were used during the rig testing portion of the program. These systems are described in detail in Paragraph 8.

The area was also used to compute such parameters as water addition requirements for humidification and fuel-air ratio correlation using the programmable computing calculator.

9.4 COMBUSTOR TEST PROCEDURES

9.4.1 Start-Up Procedure

After each of the daily pretest checks discussed in paragraph 8.8.3, the appropriate facilities were employed to supply flow and pressure to the combustor at a convenient light-off condition. The preheaters for both the cooling and the main air were turned on and the system allowed to stabilize at 150°C and the first T3 condition, respectively. The probe cooling fluid flow was also started and heated to operating temperature (150°C).

With nitrogen purge supplied to the sample line and probe, the combustor was ignited and the required condition set.

9.4.2 Humidity Control Procedure

The combustor air dewpoints of both meters were compared with each other and the National Weather Service at Sikorsky Airport which is approximately 1.6 kilometers from Lycoming. Agreement within 1°F was normally observed.

Using the ambient dewpoint and orifice parameters, the quantity of moisture in the air and actual airflow to the combustors were computed. The difference between the actual and required moisture content was then used to determine the amount of water (lb/hr) to be added.

The appropriate flow element (0-50, 0-500, or 0-5000 lb/hr) and combination of spray nozzles were selected. The operator controlling the pneumatic water valve from the control room adjusted the water flow until the displayed value corresponded to the computed flow.

As the water was added, the dewpoint measured at the combustor inlet would increase and approach the required value. Being the prime indicator of the moisture content, the dewpoint corresponding to the water concentration required was set by altering the water flow.

9.4.3 Fuel Temperature Control

The temperature of the fuel was controlled by the two steam heat exchangers described earlier. Fuel entering the manifold was maintained at 107°C (225°F) for consistency with the average level observed during the engine test phase of the program.

9.4.4 Combustor Performance Data Acquisition

The combustor operating parameters were recorded on the DS10 Digital Data Acquisition System described in Paragraph 8.10. The data recorded at each condition included fuel flow, fuel temperature (element), fuel temperature (manifold), orifice pressure (2), orifice pressure drop (3), orifice temperature (2), inlet total pressure (3), inlet total temperature (4), water flow, and two dewpoints.

9.4.5 Emissions Data Acquisition

The emission data, including hydrocarbon, carbon monoxide, carbon dioxide, oxides of nitrogen, and smoke, were measured using the DS18 Portable Gaseous Emission System and the DS16C Portable Smoke Measurement System. These systems are described in detail in Section 8. The voltage signals from the emission instruments were recorded on the DS8 Portable Digital Data Acquisition System also described in Section 8.

Each instrument was calibrated by inputing the appropriate zero and span gases to each range being used and digitally recording the responses. Successive calibrations were compared to assure that zero and span shifts did not exceed two percent during the test period.

The emission system was selected for the sample mode, and the pneumatic-actuated control valve at the input to the sample line was adjusted for the proper pressure and flow to the system. System pressures, temperatures, and flows were monitored to verify that each were within operating limits.

Visual observation of the emission levels recorded on the strip chart was used to determine stabilization. When stable, the data were recorded at 15-second intervals (two samples with the NO/NO_x analyzer in the NO mode and two in the NO_x mode). Each scan consisted of recording the output of the four emission instruments, the sample pressure and temperature of each, and the ranges being used. All of the data were taken within one hour of the last instrument calibration.

While the emissions were being digitally recorded, they were also being manually recorded and converted to engineering units. Each value was examined for consistency with expected trends, and the emission fuel-air ratio was computed. The measured fuel-air ratio was computed and compared with the emissions value to determine representiveness of the sample.

At the completion of the emission sample acquisition, the sample was redirected for a smoke sample. After a one-minute charging of the system and five-minute "bypass" stabilization, four samples at 3, 4, 7, and 11 liters passing through the filter paper were made. The sample pressures, flows, and temperatures were also recorded.

9.5 COMBUSTOR DATA REDUCTION

The punched paper tape from the DS10 (performance data) and DS8 (emission data) acquisition systems was interpreted and converted for transmission to the Lycoming IBM 360 computer system.

The data were inspected for errors, edited, and processed using the K136 Combustor Performance Data Reduction Program and K135 Emissions Data Reduction Program. The reflectance of the smoke deposit on the filter paper was measured with a McBeth Reflection Densitometer and processed using K134 Smoke Data Reduction Program.

The punched-cards output from each of the three programs were then combined in the predetermined format and shipped to Calspan Technology Products.

9.6 COMBUSTOR DATA

The combustor data (Appendix B) obtained during the rig test program were transmitted to Calspan for analysis.

10.0 ENGINE VERIFICATION TESTING

10.1 GENERAL

The engine test portion of the program was conducted on a standard ALF 502 Lycoming turbofan engine under varied uncontrolled inlet conditions to obtain emissions data over the full power range. Tests were run at seven power levels under seven different ambient conditions.

The installation of the engine was in accordance with Lycoming's normal procedures, and the engine carried the standard compliment of performance monitoring instrumentation in addition to the emissions measurement equipment. The test cell and facilities and operational procedures are described in detail in this section.

10.2 TEST FACILITIES

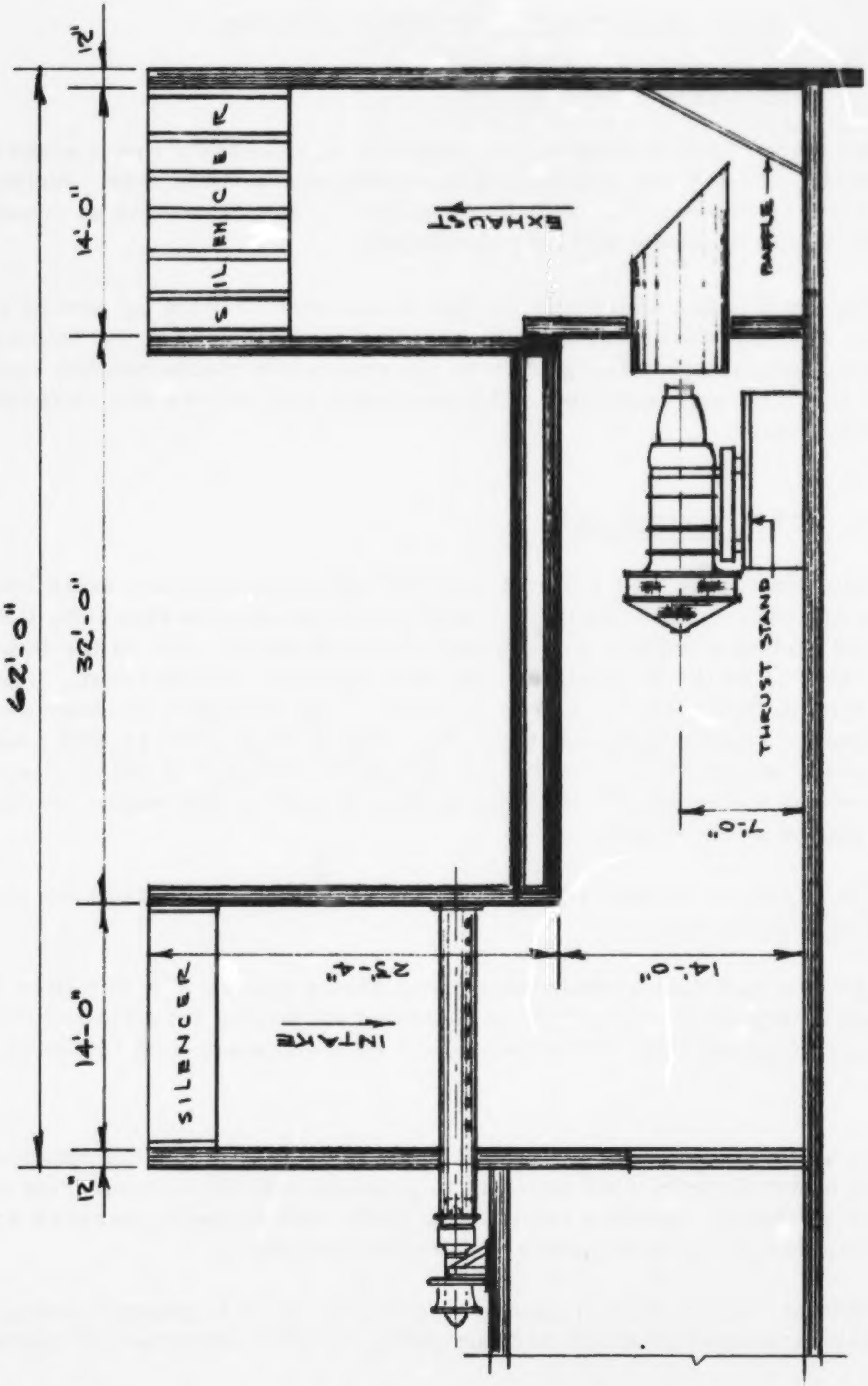
Eighteen engine test cells of various configurations are available at the Avco Lycoming Stratford facilities for sea-level testing of turboshaft, turboprop, turbojet, and turbofan engines both indoors and outdoors. One of the indoor facilities, the T13 in the Building 16 complex was used for this test. The test cell (a U-type configuration) is shown schematically in Figure 10-1 with the engine suspended from a Osmond thrust bed with a range of 0--10,000 pounds and an accuracy of ± 0.1% full scale. A bellmouth mounted to the engine inlet and pressure and temperature instrumentation located in the engine were used to determine engine performance.

The engine is connected to the various control and instrument systems illustrated in Figure 10-2.

The test cell fuel system uses fuels drawn from a 378,500 liter fuel drum. Sound attenuation equipment is installed within the intake and exhaust sections capable of passing 600 lb/sec of air with attenuation of 130 to 90 db outside the cell.

Up to 20 variables are displayed on a CRT just above the console. The display was updated every four seconds to provide real time monitoring of such parameters as thrust, ambient conditions, SFC, compressor pressure ratio, inlet airflow, and high-temperature turbine temperature.

The data acquisition sequence was initiated via keyboard control of the remotely located acquisition and computing system described in Section 8.



62'-0"
12"
14'-0"
32'-0"
14'-0"
12"
SILENCER
EXHAUST
BAFFLE
THRUST STAND
7'-0"
23'-4"
14'-0"
INTAKE
SILENCER

Figure 10-1. Test Cell 13 Schematic.

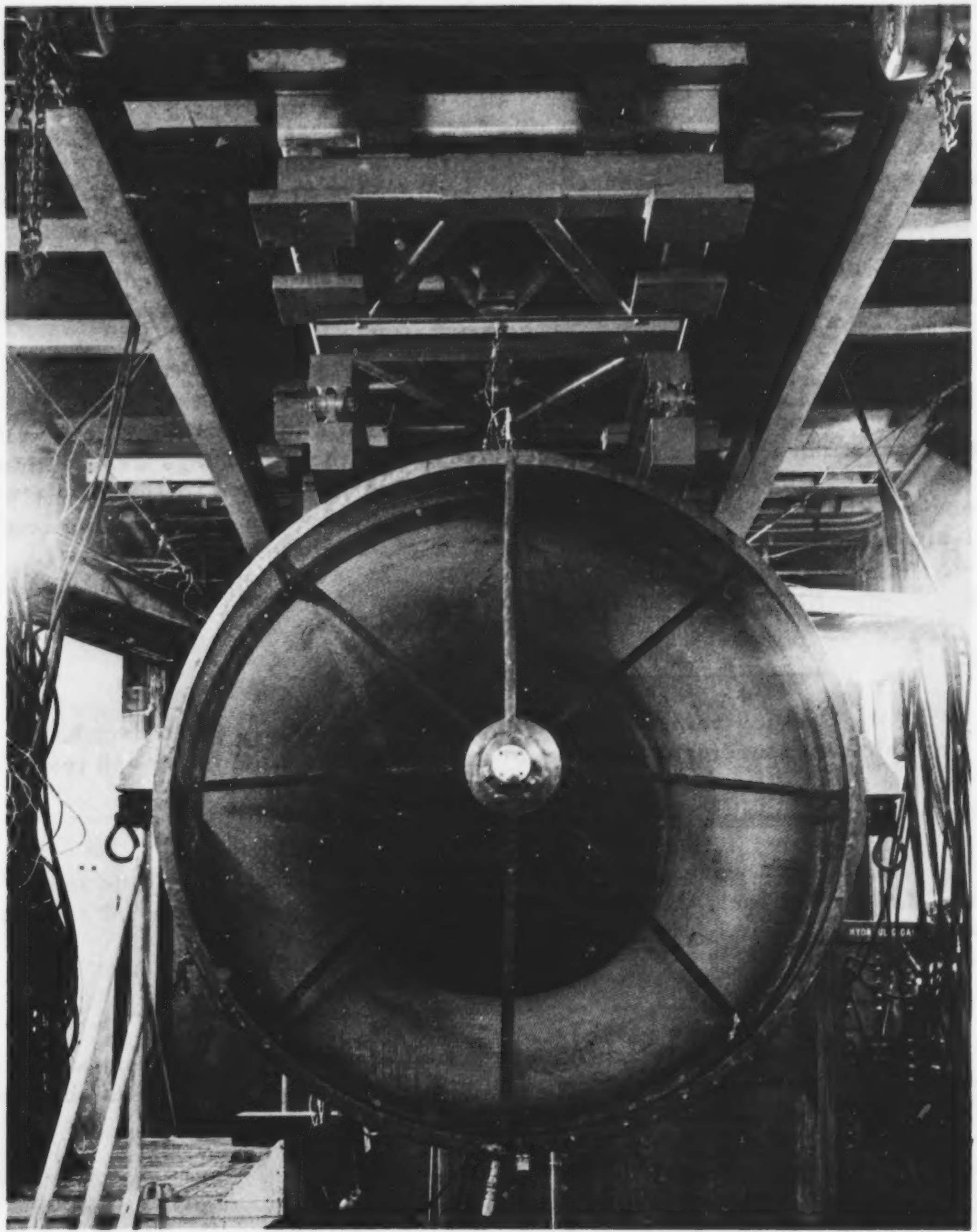


Figure 10-2. ALF 502 Engine Mounting.

10.3 ENGINE GAS SAMPLING SYSTEM

The gas sampling probe described in paragraph 8.3 was mounted to a supporting frame at the rear of the engine as shown in Figure 10-3. A 9.525 mm (0.375 in.) O.D. stainless steel heated line was connected to the probe and extended down to the base of the stand. A 18.3 meter (60 ft), 9.525 mm O.D. stainless steel heated line connected the 1.83 meter (6 ft) section with the emission system.

The two sections of sample line are independently controlled by Dekoron,Model 1660, temperature controllers with thermistor feedback. The thermistors are located at the end of the 1.83 meter section away from the sample probe and at the emission system end of the 18.3 meter section.

The stand was positioned so that the probe aligned with the centerline of the exhaust nozzle and aligned axially such that the probe legs were within 6.35 mm (0.25 in.) of the nozzle. Although the probe tended to separate from the engine, the nozzle remained within the probe shroud at all operating conditions. Fuel-air ratio correlation gave no indication of sample dilution by fan air.

10.4 ENGINE TEST PROCEDURES

10.4.1 Pre-Engine Test Checks

All of the instrument and system checks described in Section 8.0 (the Emission Measurement Technique) were performed prior to each test day.

10.4.2 Acquisition Sequence

Engine data were acquired in the following order: 1) taxi idle (out), 2) takeoff, 3) climb-out, 4) cruise 1, 5) cruise 2, 6) approach, 7) 1/2 idle, and 8) taxi idle (in).

10.4.3 Stabilization

Stabilization was determined by visual observation of the engine operating parameters at the console and the plotted emissions data. The emissions were required to remain unchanged for approximately five minutes.

10.4.4 Engine Performance Data Acquisition

The engine performance data were recorded on the IBM 1800 Computer Data Acquisition System. A sample listing of the data is shown in Figure 10-4. One scan at each condition was taken.

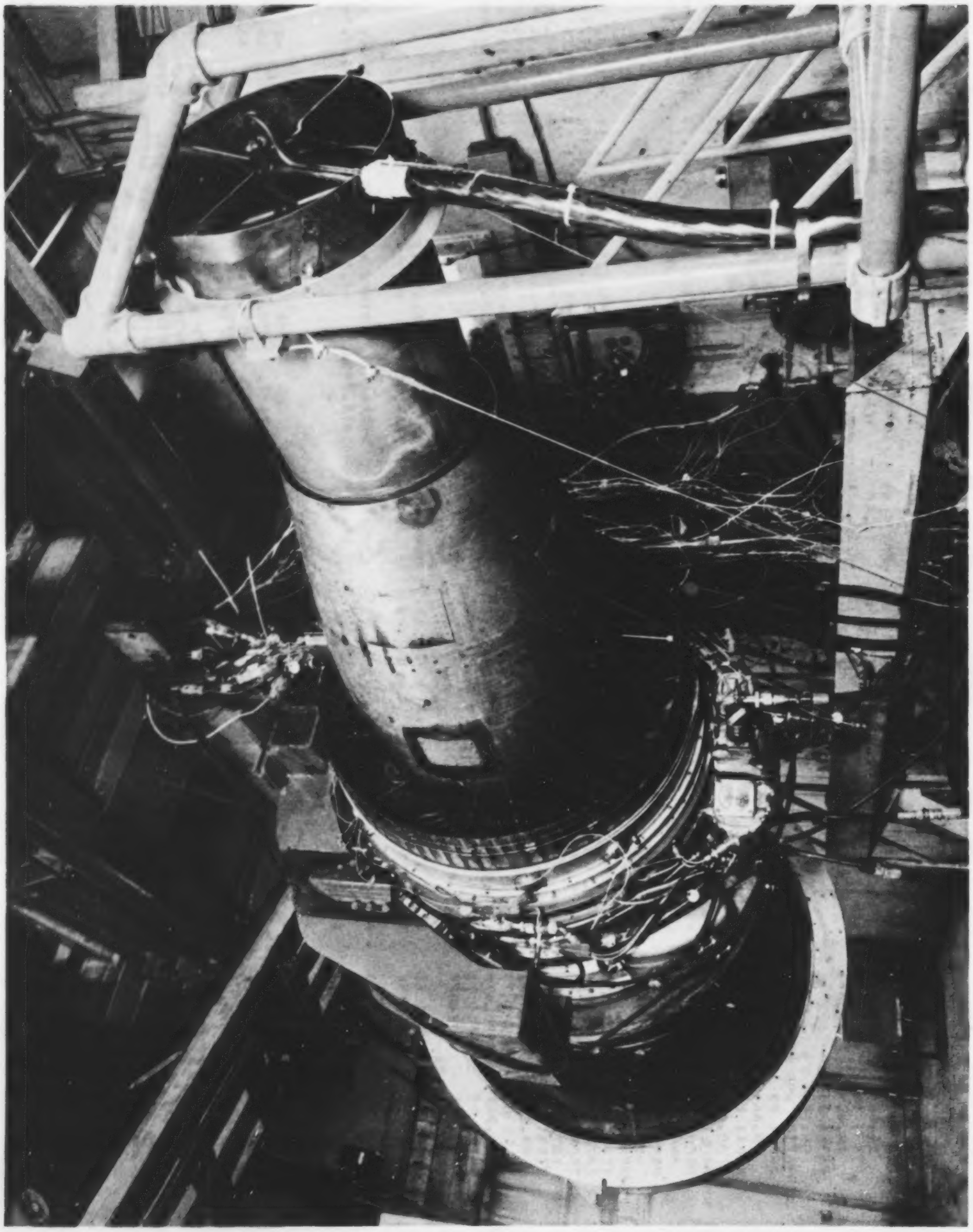
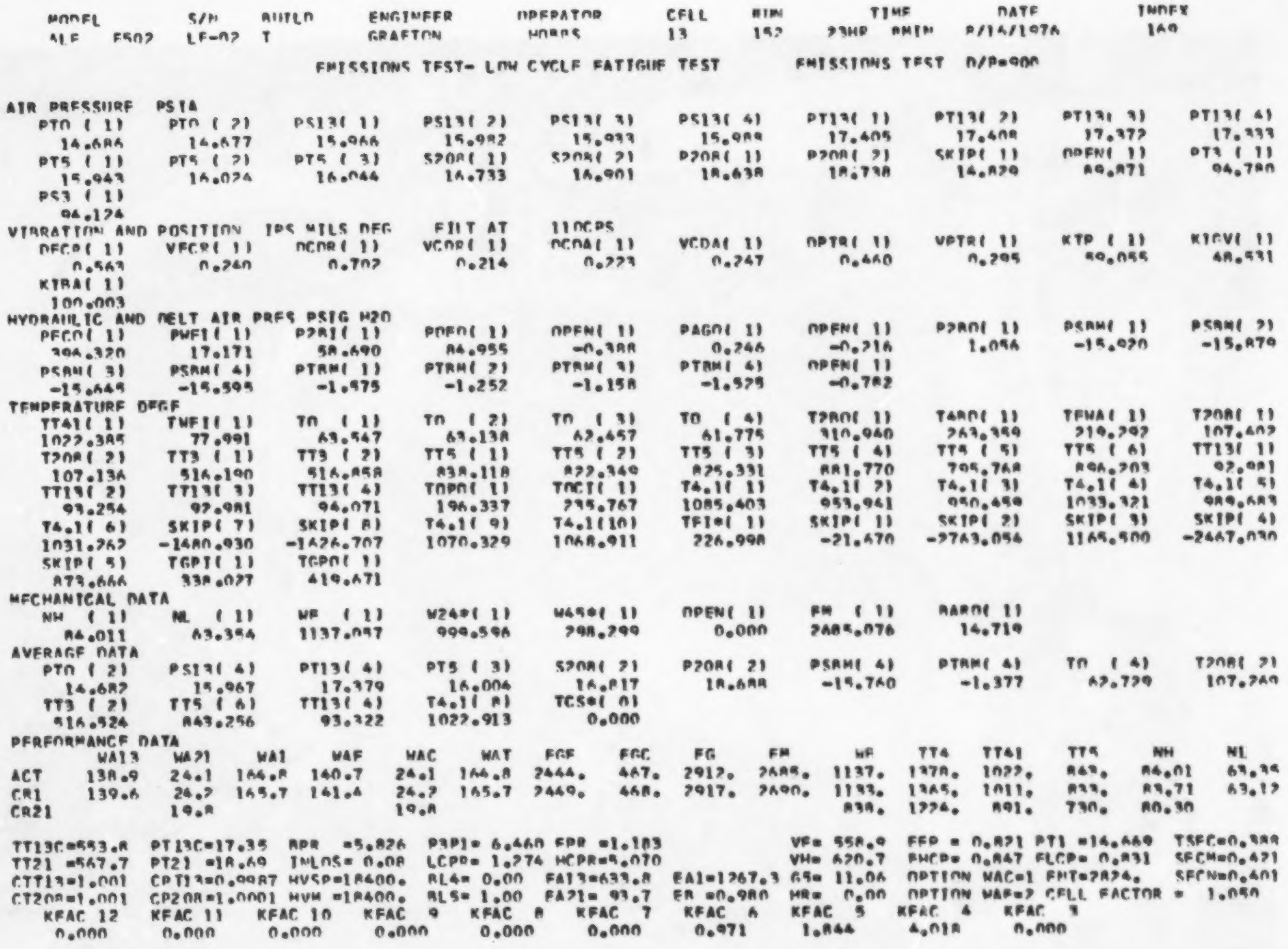


Figure 10-3. ALF 502 Gas Sample Probe Installation.



```
MODEL          S/N     BUILD    ENGINEER      OPERATOR      CELL    RUN         TIME           DATE             INDEX
ALF   F502    LF-02    T        GRAFTON       HOBBS         13      152     23HR  8MIN     8/14/1976          169

                              EMISSIONS TEST- LOW CYCLE FATIGUE TEST        EMISSIONS TEST  D/P=900

AIR PRESSURE  PSIA
   PT0 ( 1)     PT0 ( 2)     PS13( 1)     PS13( 2)     PS13( 3)     PS13( 4)     PT13( 1)     PT13( 2)     PT13( 3)     PT13( 4)
    14.686       14.677       15.966       15.982       15.933       15.989       17.405       17.408       17.372       17.333
   PT5 ( 1)     PT5 ( 2)     PT5 ( 3)     S20R( 1)     S20R( 2)     P20R( 1)     P20R( 2)     SKIP( 1)     OPEN( 1)     PT3 ( 1)
    15.943       16.024       16.044       16.733       16.901       18.638       18.738       14.829       89.871       94.780
   PS3 ( 1)
    96.124
VIBRATION AND POSITION  IPS MILS DEG    FILT AT     110CPS
   DFCR( 1)     VFCR( 1)     DCDR( 1)     VCDR( 1)     DCDA( 1)     VCDA( 1)     DPTR( 1)     VPTR( 1)     KTP ( 1)     KIGV( 1)
     0.563        0.240        0.702        0.214        0.223        0.247        0.460        0.295       59.055       48.531
   KIBA( 1)
   100.003
HYDRAULIC AND DELT AIR PRES PSIG H2O
   PFCO( 1)     PWFI( 1)     P2RI( 1)     PDFO( 1)     OPEN( 1)     PAGO( 1)     OPEN( 1)     P2RO( 1)     PSAM( 1)     PSAM( 2)
   396.320       17.171       58.690       84.955       -0.388        0.246       -0.216        1.096      -15.920      -15.879
   PSAM( 3)     PSAM( 4)     PTRM( 1)     PTRM( 2)     PTRM( 3)     PTRM( 4)     OPEN( 1)
   -15.649      -15.595       -1.575       -1.252       -1.158       -1.579       -0.782
TEMPERATURE DEGF
   TT41( 1)     TWFI( 1)     T0  ( 1)     T0  ( 2)     T0  ( 3)     T0  ( 4)     T2RO( 1)     T4RO( 1)     TEWA( 1)     T20R( 1)
  1022.385       77.991       63.547       63.138       62.457       61.775      310.960      263.359      219.292      107.402
   T20R( 2)     TT3 ( 1)     TT3 ( 2)     TT5 ( 1)     TT5 ( 2)     TT5 ( 3)     TT5 ( 4)     TT5 ( 5)     TT5 ( 6)     TT13( 1)
   107.136      516.190      516.858      838.118      822.349      825.331      881.770      795.768      896.203       92.981
   TT13( 2)     TT13( 3)     TT13( 4)     TOPO( 1)     TOCI( 1)     T4.1( 1)     T4.1( 2)     T4.1( 3)     T4.1( 4)     T4.1( 5)
    93.254       92.981       94.071      196.337      235.767     1085.403      953.941      950.459     1033.321      989.683
   T4.1( 6)     SKIP( 7)     SKIP( 8)     T4.1( 9)     T4.1(10)     TFI*( 1)     SKIP( 1)     SKIP( 2)     SKIP( 3)     SKIP( 4)
  1031.262    -1480.930    -1426.707     1070.329     1068.911      226.998      -21.470    -2763.056     1165.500    -2467.030
   SKIP( 5)     TGPI( 1)     TGPO( 1)
   873.666      338.027      419.671
MECHANICAL DATA
   NH  ( 1)     NL  ( 1)     WF  ( 1)     W24*( 1)     W45*( 1)     OPEN( 1)     FN  ( 1)     BARO( 1)
    84.011       63.354     1137.097      999.596      298.299        0.000     2685.076       14.719
AVERAGE DATA
   PT0 ( 2)     PS13( 4)     PT13( 4)     PT5 ( 3)     S20R( 2)     P20R( 2)     PSAM( 4)     PTRM( 4)     T0  ( 4)     T20R( 2)
    14.682       15.967       17.379       16.004       16.817       18.688      -15.760       -1.377       62.729      107.269
   TT3 ( 2)     TT5 ( 6)     TT13( 4)     T4.1( 8)     TCS*( 0)
   516.524      843.256       93.322     1022.913        0.000
PERFORMANCE DATA
         WA13    WA21     WA1     WAF     WAC     WAT    FGF    FGC     FG     FN      WF     TT4    TT41    TT5      NH      NL
ACT     138.9    24.1   164.8   140.7    24.1   164.8  2444.   467.  2912.  2685.   1137.   1378.   1022.   863.   84.01   63.35
CR1     139.6    24.2   165.7   141.4    24.2   165.7  2449.   468.  2917.  2690.   1133.   1365.   1011.   833.   83.71   63.12
CR21             19.8                    19.8                                        838.   1224.    891.   730.   80.30

TT13C=553.8  PT13C=17.35  BPR  =5.826  P3P1= 6.460 FPR =1.183              VF= 558.9  FFP = 0.821 PT1 =14.669  TSFC=0.388
TT21 =567.7  PT21 =18.69  INLOS= 0.08  LCPR= 1.274 HCPR=5.070              VH= 620.7  FHCP= 0.847 FLCP= 0.831  SFCM=0.421
CTT13=1.001  CPT13=0.9987 HVSP=18400.  BL4= 0.00  FA13=633.8  EA1=1267.3 G5= 11.06  OPTION WAC=1 FNT=2824.   SFCN=0.401
CT20R=1.001  CP20R=1.0001 HVM =18400.  BL5= 1.00  FA21= 93.7  ER =0.980  HR=  0.00  OPTION WAF=2 CELL FACTOR =  1.050
   KFAC 12    KFAC 11    KFAC 10    KFAC  9    KFAC  8    KFAC  7    KFAC  6    KFAC  5    KFAC  4    KFAC  3
    0.000      0.000      0.000      0.000      0.000      0.000      0.971      1.844      4.018      0.000
```

Figure 10-4. Engine Performance Data Listing - Sample.

10.4.5 Emissions Data Acquisition

The emissions data - including hydrocarbon, carbon monoxide, carbon dioxide, oxides of nitrogen, and smoke - were measured using the DS18 Portable Gaseous Emission and DS16C Portable Smoke Measurement System, respectively. Both systems are described in Section 8.0. The signals from the emissions instruments were recorded on the DS8 Portable Digital Data Acquisition System also described in Section 8.0. Calibration of each instrument was digitally recorded at the required intervals and checked for shifts in the zero and span of less than 2 percent as compared with the previous calibration.

Four scans of the data were recorded at 15-second intervals: two with the NO_x analyzer in the "NO" mode, and two while in the "NO_x" mode. Each scan consisted of recording the output of each of the four instruments, the pressure and temperature of the sample entering the sensor, and the instrument range being used. Each data point was taken within one hour of the last instrument calibration.

The emission values were converted to engineering units and used to compute the fuel-air ratio for comparison with the measured value from the IBM 1800 performance data.

The emission system was switched to the "smoke sample" mode for redirecting the sample to the DS16C smoke meter. After the required one-minute system charging and five-minute "bypass" stabilization, the four samples at 3, 4, 7, and 11 liters through the filter paper were made.

10.5 ENGINE DATA REDUCTION

The punched paper tape from the DS8 Digital Data Acquisition System was interpreted by a photoreader converter system and transmitted to Lycoming's IBM 360 computer system.

The emission data were inspected for errors, edited, and processed, using the K135 Emission Data Reduction Program. The reflectance of the smoke deposit on the filter paper was measured with the McBeth model RD-400 reflection densitometer and processed using K134 Smoke Data Reduction Program. The punch-cards output from each was combined with the engine performance data in the predetermined format and prepared for shipment to Calspan Technology Products. The indicated core airflow has been adjusted for the bleed air (13%) at idle and 1 1/2 idle and overboard leakage (2%) at all conditions. The turbine cooling air, however, has not been deducted so as to represent the airflow seen by the gas sample probe.

10.6 ENGINE DATA

The data (Appendix C) obtained from the engine test program was transmitted to Calspan Technology Products for analysis.

11.0 DISCUSSION

11.1 GENERAL

The purpose of the testing accomplished under this program was to provide combustor test rig and full engine emissions data for later analysis and correlation. The engine selected was a Lycoming ALF 502 turbofan in the T-1 class category. The testing accomplished provides a wide variation of operational and ambient conditions which form a substantial data base for subsequent development of ambient correction factors.

The data accumulated from this testing has been reduced in the form of plots showing general effects and trends of conditions on emission levels. These plots are presented herein.

11.2 FUEL-AIR RATIO CORRELATION

The criterion used for sample representativeness was the correlation of emission fuel-air ratio with measured fuel and airflow.

The combustor fuel-air ratio correlation averaged less than 2 percent at all simulated power conditions.

The engine and rig fuel-air ratio correlation was acceptable at all power levels. The average percentage differences between the measured and emission (gas analysis) value $\left(\frac{F/A_{meas} - F/A_{G.A.}}{F/A_{G.A.}}\right)$ were as follows:

Power Level	Average Diff. (%) Engine Test	Average Diff. (%) Rig Test
Taxi Idle (out)	2.7	1.26
Takeoff	5.4	- - -
Climbout	5.0	- - -
Cruise No. 2	1.1	- - -
Cruise No. 1	0.9	- - -
Approach	1.1	1.28
1 1/2 Idle	3.5	1.25
Taxi Idle (in)	2.0	- - -

The better correlation in the rig testing is due to the more precise measurement of combustor airflow than is possible in the full engine.

11.3 HUMIDITY CORRELATION

The two humidity measurement methods used during the combustor rig test consistently agreed over the range of operation.

Selected voltage values from the two dew point meters (ambient air and rig air) were input in tabular form of voltage versus degree Centigrade to the computer program.

The humidity (R) at each station was computed from its respective temperature (T, °F) using Equation (1). The polynomial coefficients for the partial pressure operation was developed using a calculator program (Reference 3) by inputing temperatures and associated values of vapor pressure over the expected operating range (0°-100°F) from the table of water vapor pressures presented in Reference 4.

$$R \text{ (Grains of } H_2O\text{/lb of dry air)} = \frac{0.62192 \, Pv}{P_{BARO} - Pv} \times 7000 \quad (1)$$

where

$$Pv \text{ (Partial Press.)} - 4.58062914 + 3.327097623E\text{-}1T + 1.077633396E\text{-}2 \, T^2 + 1.987127117E\text{-}4 \, T^3 + 2.102836053E\text{-}6 \, T^4 + 2.03975894E\text{-}8 \, T^5$$

and

$$P_{BARO} \text{ (mm Hg)} = P_{BARO} \text{ (PSIA)} \times \frac{760}{14.696}$$

The frequency output of the turbine elements recorded by the data acquisition system was also converted to pounds per hour of water by a table look-up routine.

The water content at the rig inlet was then determined by Equation 2.

$$R_{RIG} \text{ (Grains of } H_2O\text{/lb of dry air)} = R_{AIR} + \left(\frac{W_W}{W_a}\right) \times 7000 \quad (2)$$

where W_W = water flow (pph)

and W_a = air flow (pph)

---

(3) HP 9820A Math Pac, P/N 09820-70000, Curve Fitting by Chebyshev Polynomials, Pg. 125-130

(4) Measurements and Data, Vol. 9 No. 5, September/October 1975, Table 4, Pg. C5-C9

TA/

The average difference between the two measurement methods at each level of operation was as follows:

Nominal Humidity Level (Grains)	Average Difference (Grains)
25	1.4
35	1.3
52.5	1.7
70	2.6
105	3.4
175	4.7

11.4 ENGINE/TEST RIG EMISSIONS EQUIVALENCE

11.4.1 General

The engine verification testing appeared to give reasonably good comparison with corrected data generated in the rig test portion of the program. Since the engine test portion was run under uncontrolled ambient conditions, direct simulation of all parameters was not expected, nor achieved, between the rig and engine tests.

In order to compare the equivalence of the engine and rig tests, the rig and engine points most closely approximating standard-day conditions at the three common tested power levels have been tabulated. Combustor inlet conditions were used as the criteria for selecting the closest equivalent performance points, since the resulting emissions are dependent on these conditions. Table 11-1 presents these combustor performance comparisons and the resulting emission indexes. Examination of this table shows that there is good equivalence between most of the combustor performance parameters (independent variables) and emissions parameters (dependent variables). Some parameters, however, do not show direct correlation as presented and are discussed below. The differences in the dependent variable correlations appear due to lack of exact equivalence between the independent variables.

11.4.2 Performance Parameters (Independent Variables)

Combustor Inlet Pressure, P_3

Equivalence between the engine and rig is within the expected engine variability when compared with the engine design parameters.

Combustor Inlet Temperature, T_3

The comparison of temperature is good at all three power settings.

TABLE 11-1. COMPARISON OF ENGINE AND RIG TESTING

Parameters	IDLE			1.5 x IDLE			APPROACH		
	Rig	Engine	Diff	Rig	Engine	Diff	Rig	Engine	Diff
Test Point	001145	281117		002145	282207		003144	283307	
P_3 (psia)	35.2	32.4	+2.8	40.2	39.9	+0.3	75.2	73.2	+2.0
T_3 (°R)	684	691	-7	746	740	+6	899	905	-6
H (gr H_2O/Air)	42.3	63.3	-21.0	44.0	63.3	-19.3	44.9	62.5	-17.6
W_f (pph)	349	365	-16	416	442	-26	804	778	+26
W_a (meas) pps	7.3	8.1	-0.8	10.7	10.1	+0.6	17.5	17.3	+0.2
F/A (measured)	.0133	.0125	+.0008	.0108	.0121	-.0013	.0128	.0125	+.0003
HC E.I.	5.46	5.23	+0.23	6.94	3.19	+3.75	0.78	0.48	+0.30
CO E. I.	39.3	42.5	-3.2	46.6	33.7	+12.9	15.0	10.8	+4.2
NO_x E. I.	2.9	3.0	-0.1	3.1	3.4	-0.3	5.1	5.8	-0.7

Absolute Humidity, H

A wide difference between engine and rig humidities exists because no equivalent engine test points were run.

Fuel Flow W_f

Fuel flows compare well between engine and rig points within expected engine variability limits.

Combustor Airflow, W_a

Airflows compare very closely at the approach conditions, but the idle and 1.5 x idle points are different in the engine and rig by between 5 to 10 percent. This variation is due to a combination of engine variability from nominal values and problems encountered in accurately extrapolating the low-power engine operating conditions from computer deck printouts of the higher power points. Engine variability (including measurement error tolerances) can account for up to 4 percent of the total difference with extrapolation of the rig points accounting for the remainder.

Combustor Fuel-Air Ratio, F/A

Since fuel-air ratio is a direct function of air and fuel flows, the variability between engine and rig points is dependent on the same causes as explained above. As with the airflow, the fuel-air ratio shows excellent agreement between rig and engine at the approach conditions, less at idle, and a significant difference at the 1.5 x idle points.

11.4.3 Emissions Parameters (Dependent Variables)

Figure 11-1 shows CO, HC, and NO_x emission indexes for rig and engine tests as a function of power level. Corrections to the CO and HC indexes shown at idle and 1.5 x idle account for the significant difference in fuel-air ratio between rig and engine test points. These are estimated corrections based on the trends exhibited during the rig testing results shown in Figures 11-11, 11-12, 11-14, and 11-15 presented in paragraph 11.5.

Taking into account the fuel-air ratio estimated corrections, reasonably good correspondence is evident between engine and rig testing. The exact degree of correspondence can be shown only when correction factors for all the variables are developed as a result of final data analysis from this and other similar programs.

Specific comments on the emission index correlations are discussed in the following paragraphs.

Hydrocarbon Emissions Index, HC E.I.

The HC E.I. shows good consistency between rig and engine at approach and idle with a difference in both cases under 0.3 in E. I. number.

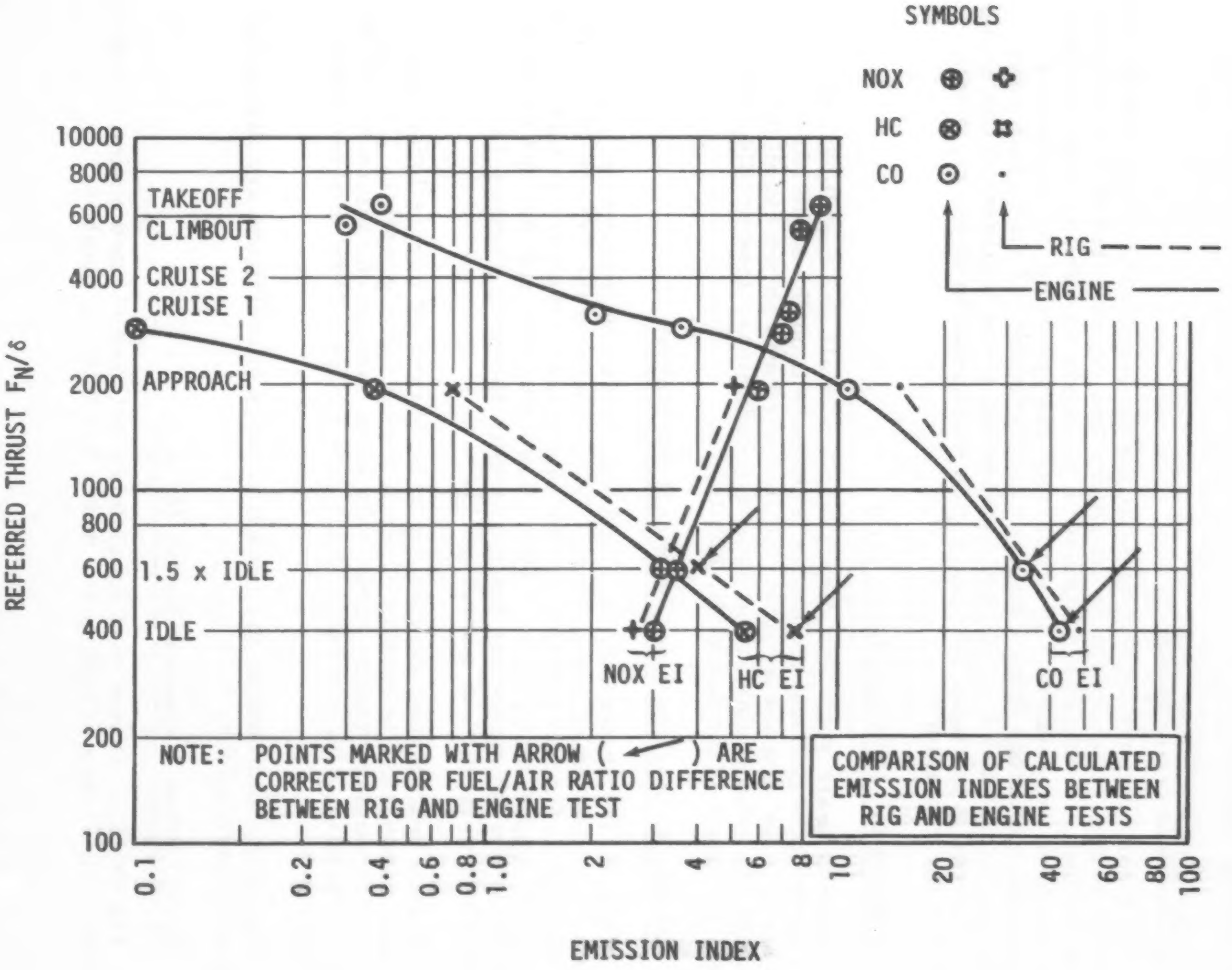


Figure 11-1. Comparison of Calculated Emission Indexes Between Rig and Engine Tests.

There is, however, a variation of 3.75 in E. I. numbers between the rig and engine at 1.5 x idle. This is not an unexpectedly larger variation for the corresponding difference in fuel-air ratios between engine (F/A = 0.0121) and rig (F/A = 0.0108), since rig data showed similar trend as evidenced by Figure 11-12.

Carbon Monoxide Emissions Index, CO E. I.

The CO E. I. shows good consistency at idle, but 1.5 x idle and approach comparisons show differences in E. I. number of 12.9 and 4.2, respectively. As with the HC E.I., the 1.5 x idle comparison between rig and engine is consistent with that expected from rig data for the difference in fuel-air ratios as indicated in Figure 11-16. The high value of CO E. I. recorded at rig approach conditions is slightly outside the range expected based upon rig test correlation with fuel-air ratio as presented again in Figure 11-16.

Oxides of Nitrogen Emission Index, NO_x E. I.

The rig NO_x levels, although lower than the corresponding engine data due to differencies in conditions, were of consistent magnitude with engine levels, and no attempt was made for further correlation.

Smoke Emissions

The smoke levels at the three lower power conditions were too low for an effective assessment of the relationship between rig and engine values.

11.5 DATA PLOTS

Figures 11-2 through 11-31 consist of uncorrected data referenced to parameters affecting the emission levels or pertinent relationships of one component to the other. No curve fitting techniques were used.

The figures include data from the combustor rig test at each simulated power level, test condition, and engine emission data. The test condition nomenclature on each plot refer to the engine and rig ambient conditions indicated in Tables 2-2 and 2-3 respectively.

Figures 11-2 through 11-4 show the rig data correlation of CO Emission Index (E. I.) to HC Emission Index at each test condition for idle, 1.5 x idle, and approach.

Figures 11-5 through 11-10 show the rig test data correlation of CO and HC Emission Index to T_{t3} for each test condition for the three power levels.

Figures 11-11 through 11-19 indicate the relation of each rig gaseous emission component to the fuel-air ratio.

Figures 11-20 through 11-22 correlate the rig NO_x Emission Index to the combustor inlet temperature (T_3) at each rig test power level.

Figures 11-23 through 11-27 show the CO - HC Emission Index relationship, fuel-air ratio effect (one each component), and T3 on the NO_x Emission Index for the seven engine tests.

Figures 11-28 through 11-31 show each exhaust constituent measured, including smoke number for the seven engine tests as a function of referred thrust.

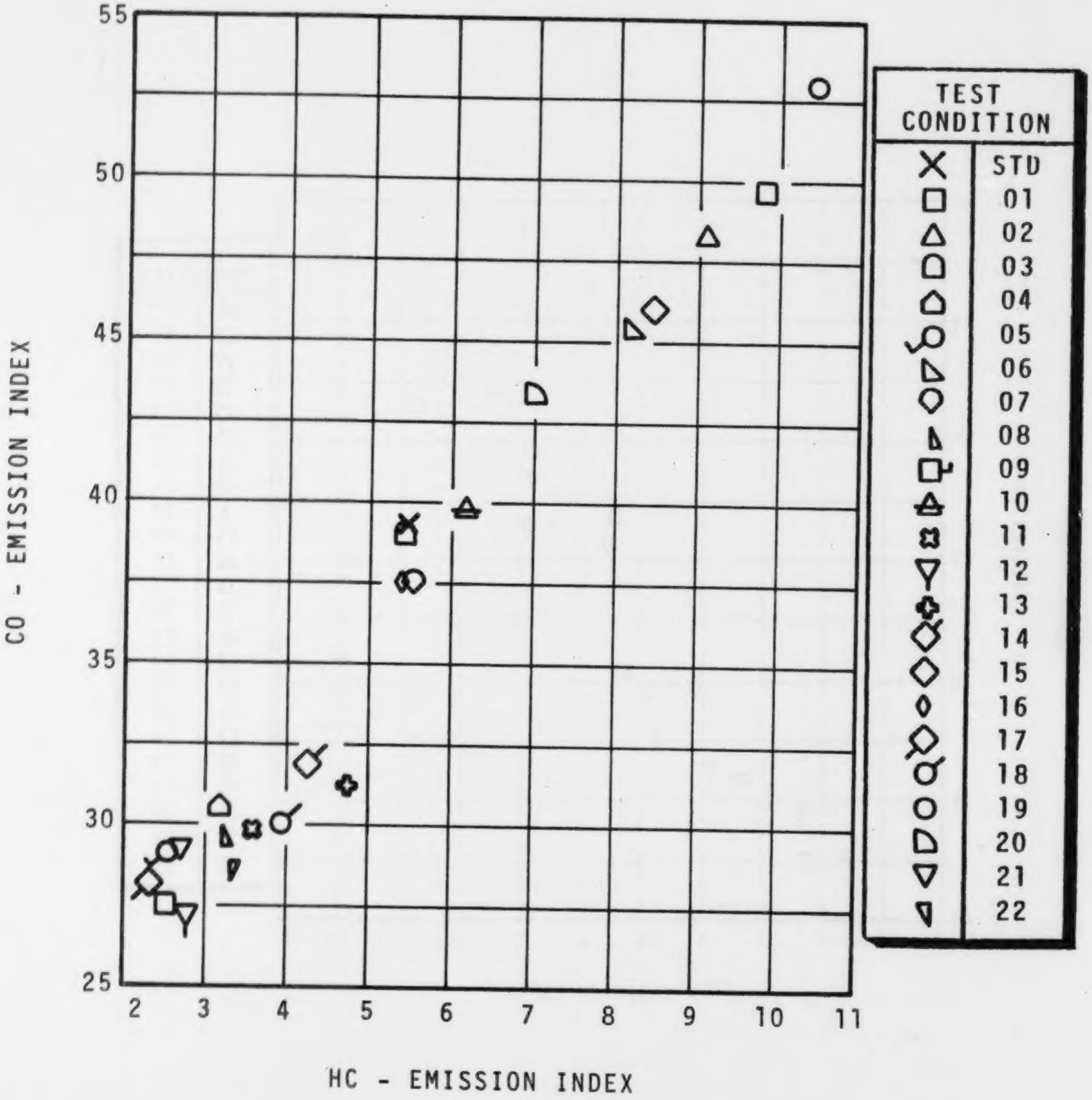


Figure 11-2. CO Emission Index Versus HC Emission Index, Rig Test - Idle.

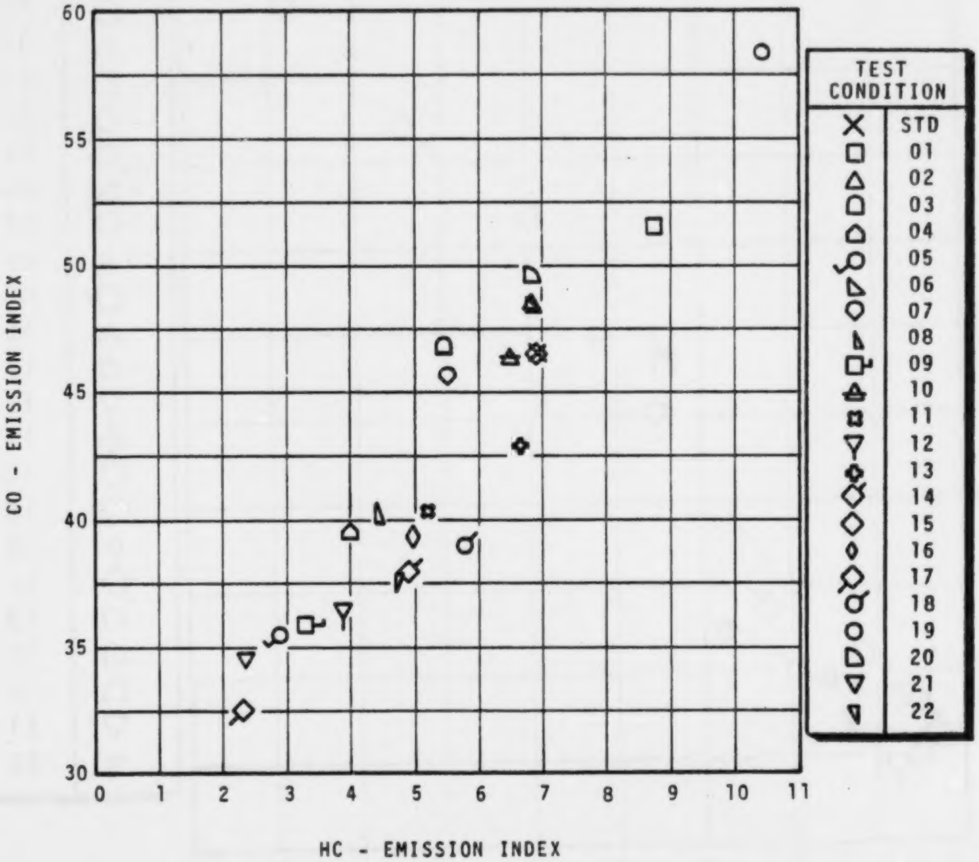


Figure 11-3. CO Emission Index Versus HC Emission Index, Rig Test - 1.5 x Idle

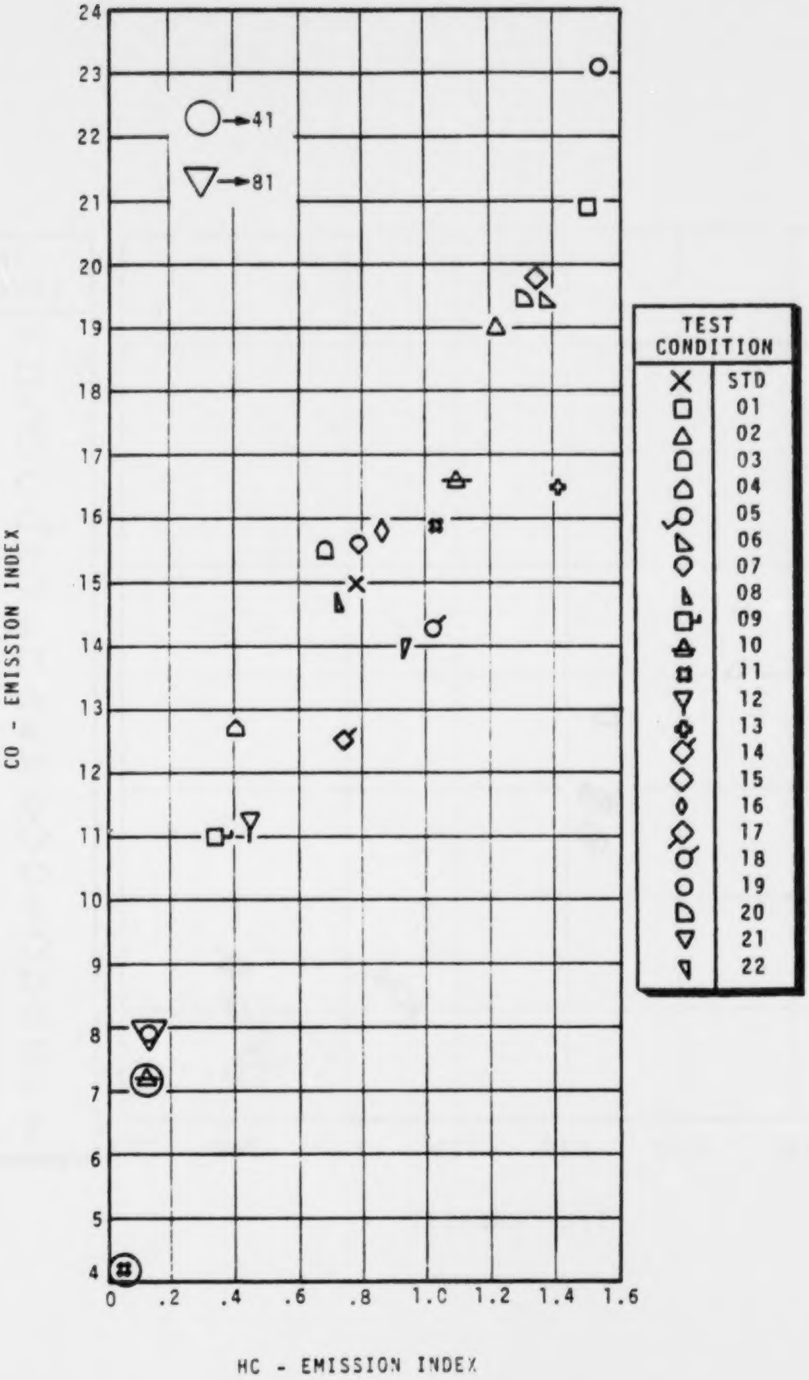


Figure 11-4. CO Emission Index Versus HC Emission Index, Rig Test - Approach.

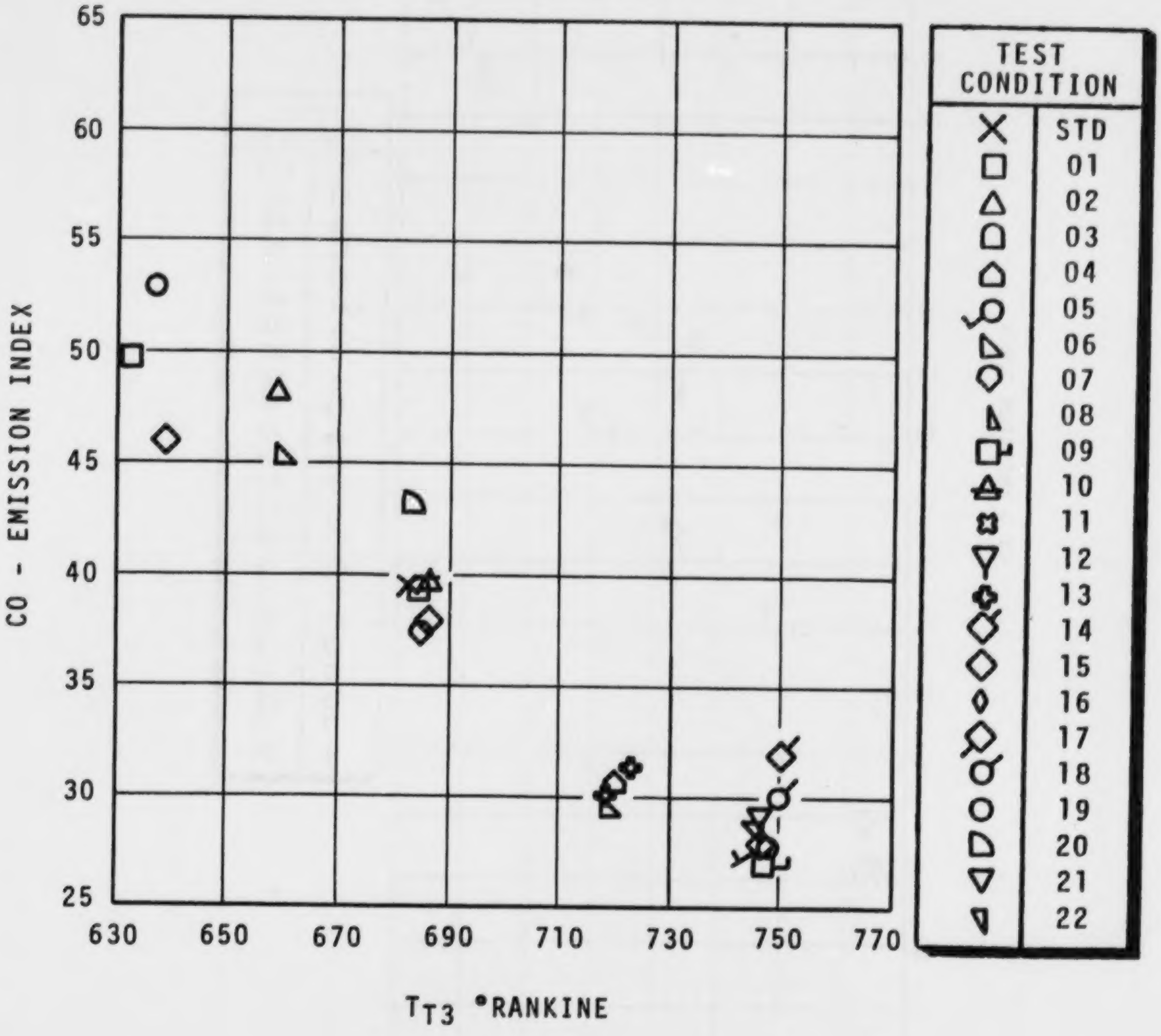


Figure 11-5. CO Emission Index Versus Tt3 Rig Test, Idle.

Tn

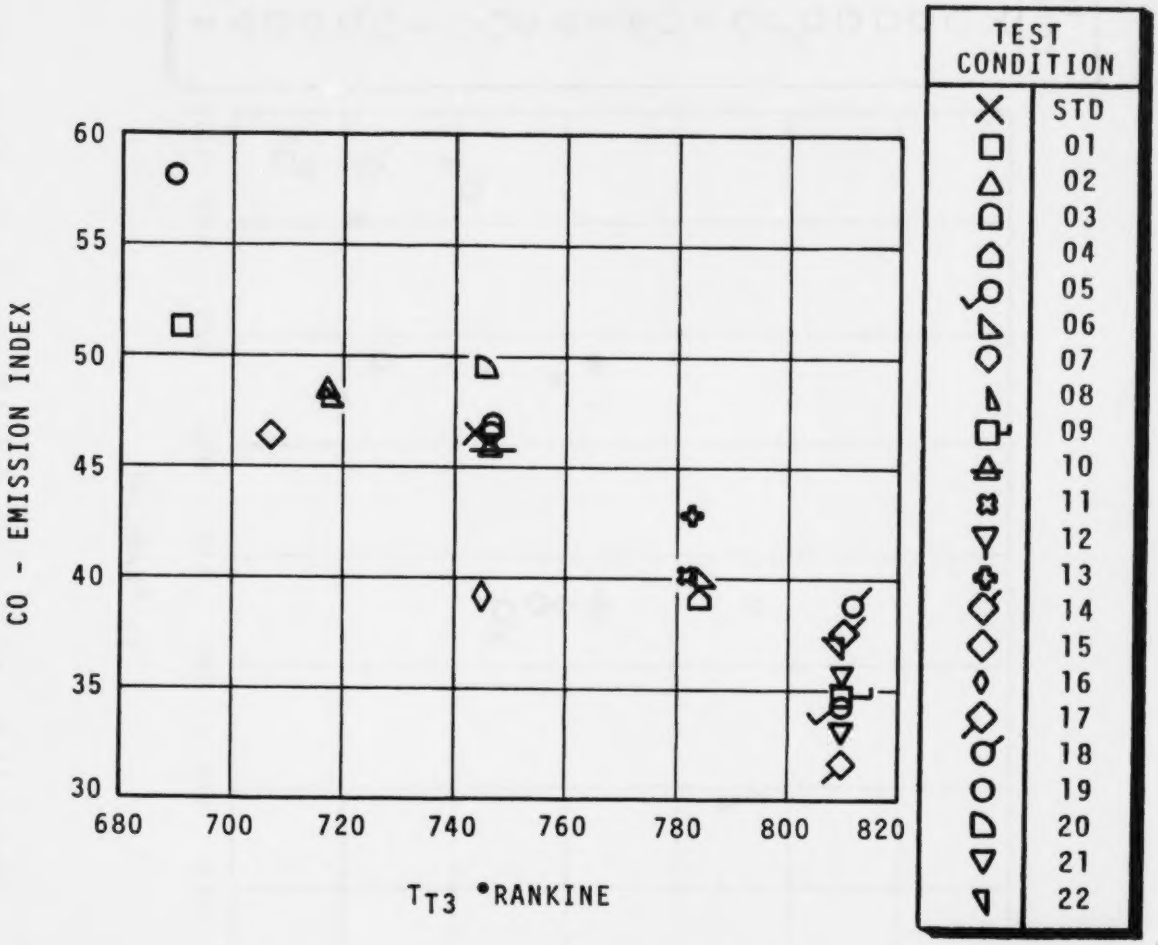


Figure 11-6. CO Emission Index Versus T_{t3} Rig Test, 1.5 x Idle.

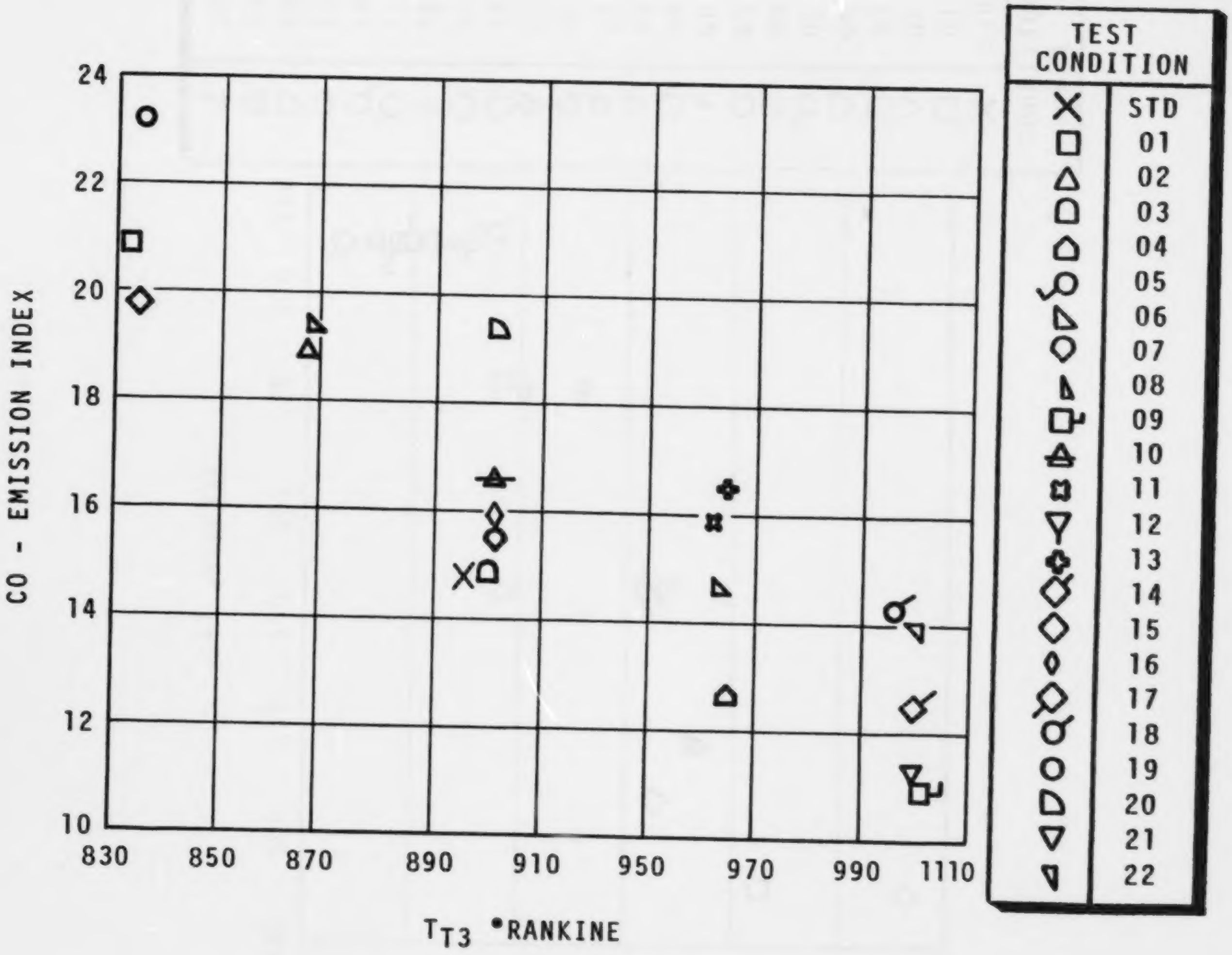


Figure 11-7. CO Emission Index Versus T_{t3} Rig Test, Approach.

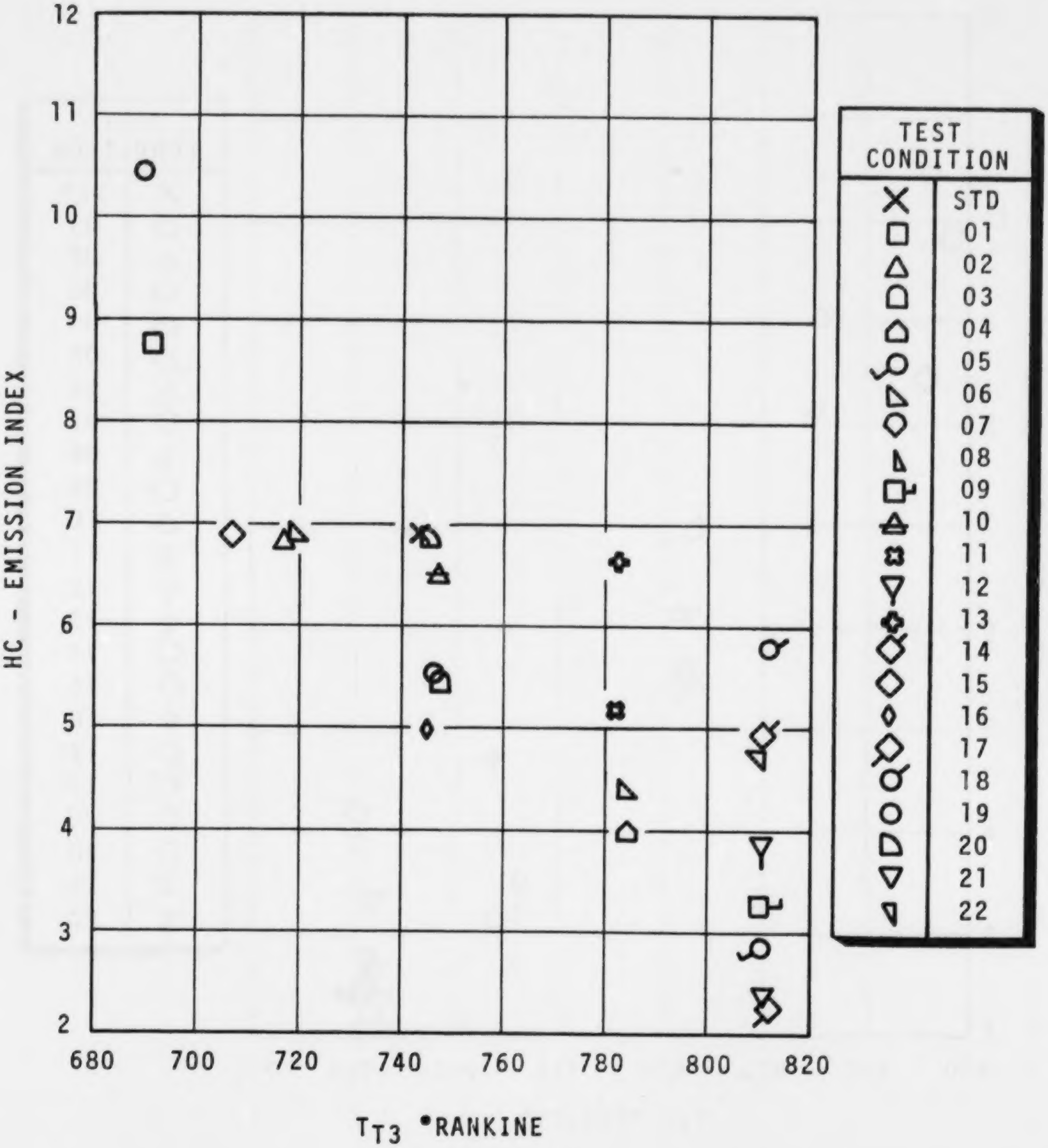


Figure 11-8. HC Emission Index Versus T_{t3} Rig Test, Idle.

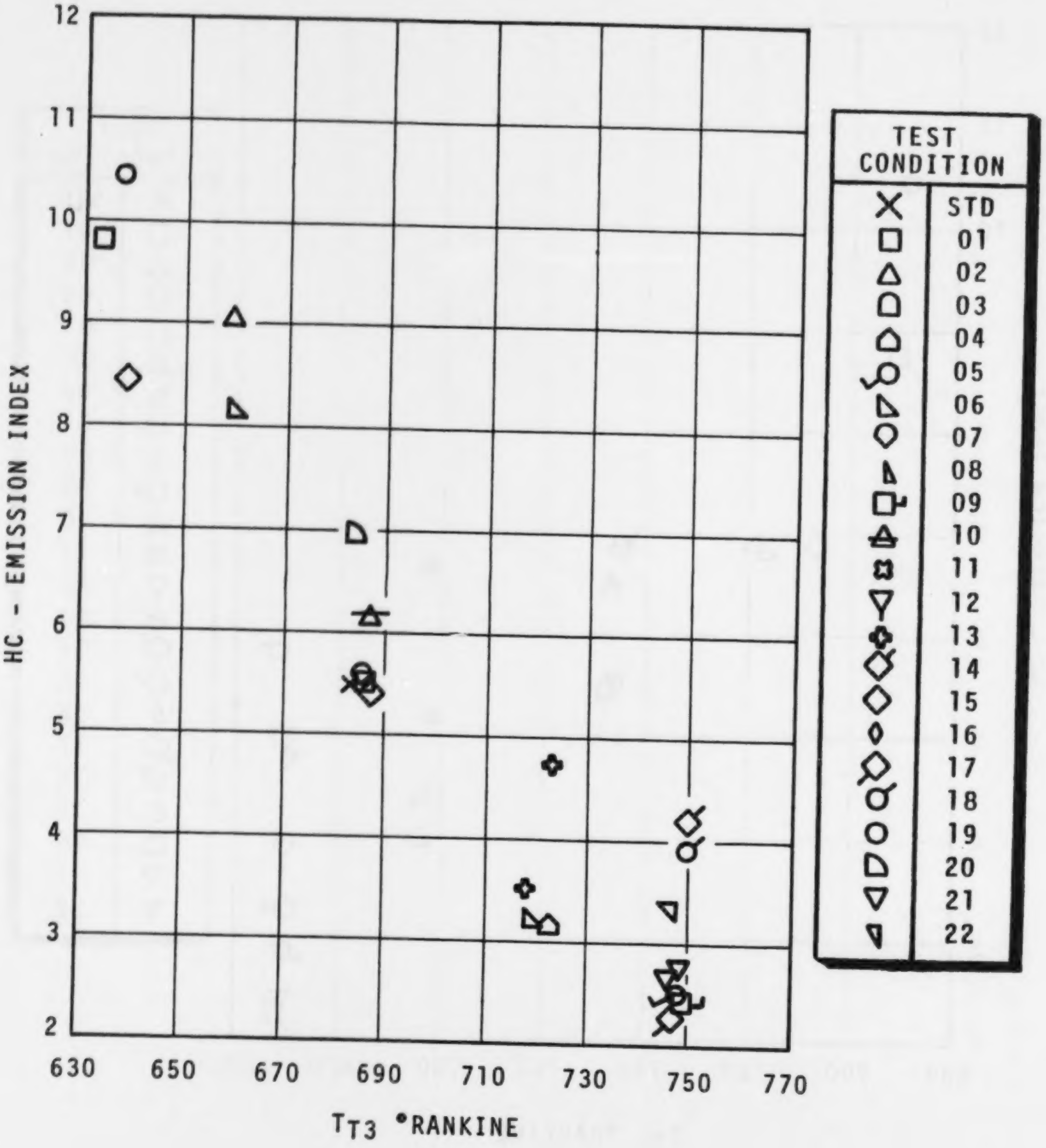


Figure 11-9. HC Emission Index Versus T_{t3} Rig Test, 1.5 x Idle.

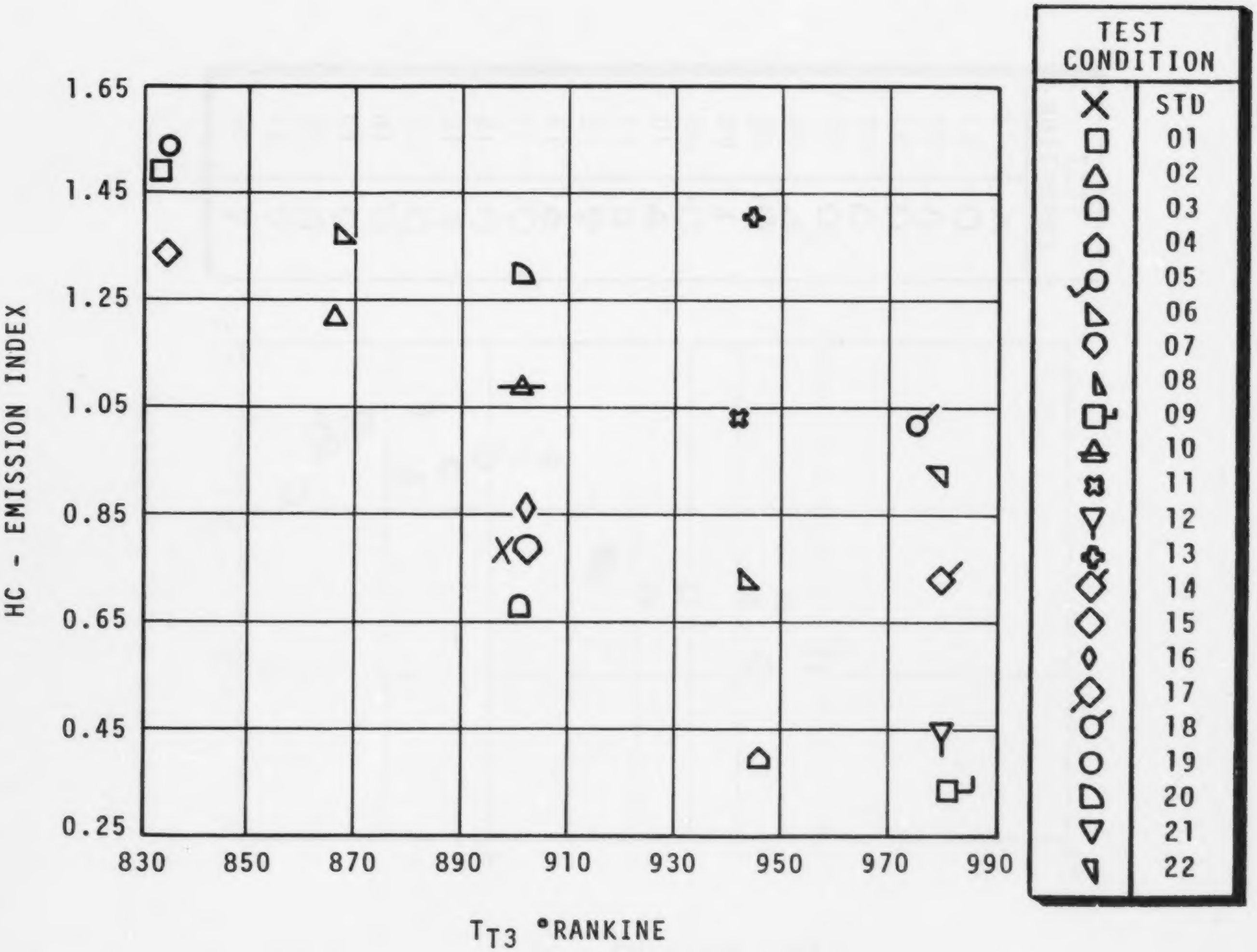


Figure 11-10. HC Emission Index Versus T_{t3} Rig Test, Approach.

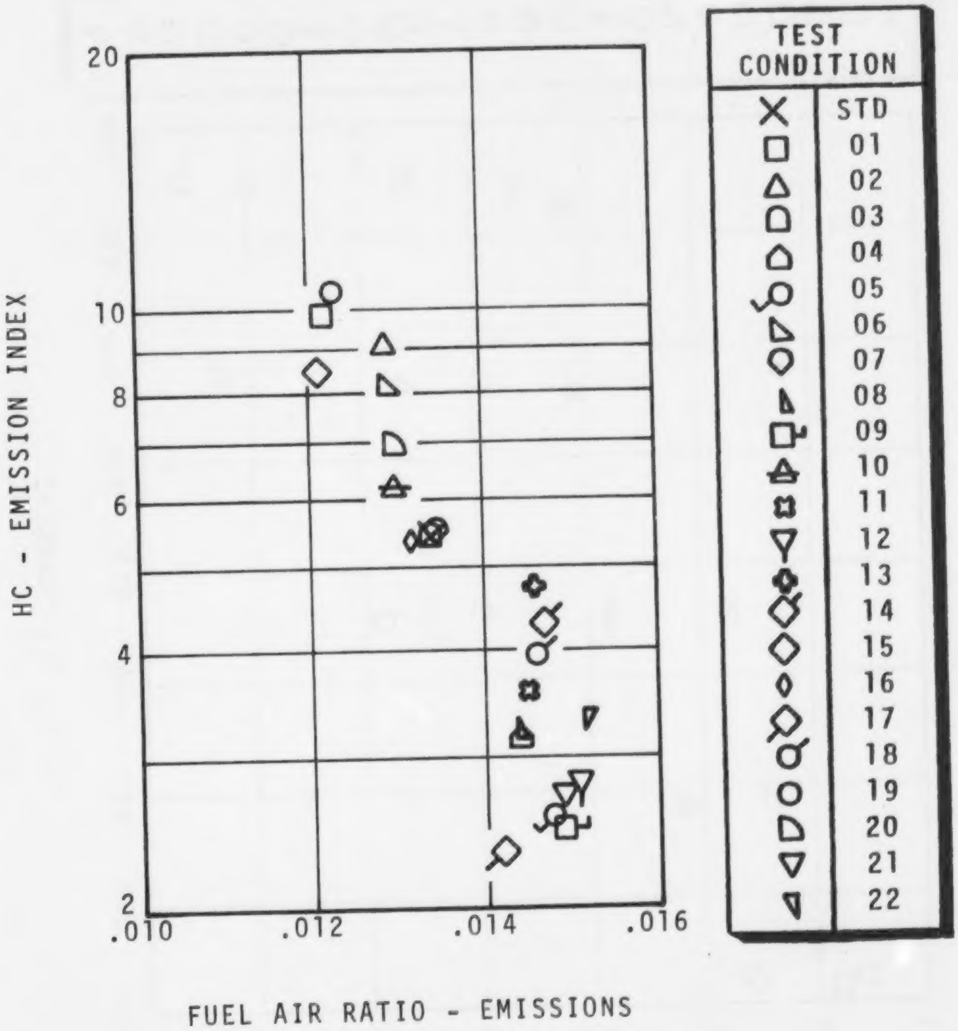


Figure 11-11. HC Emission Index Versus Fuel-Air Ratio, Rig Test - Idle.

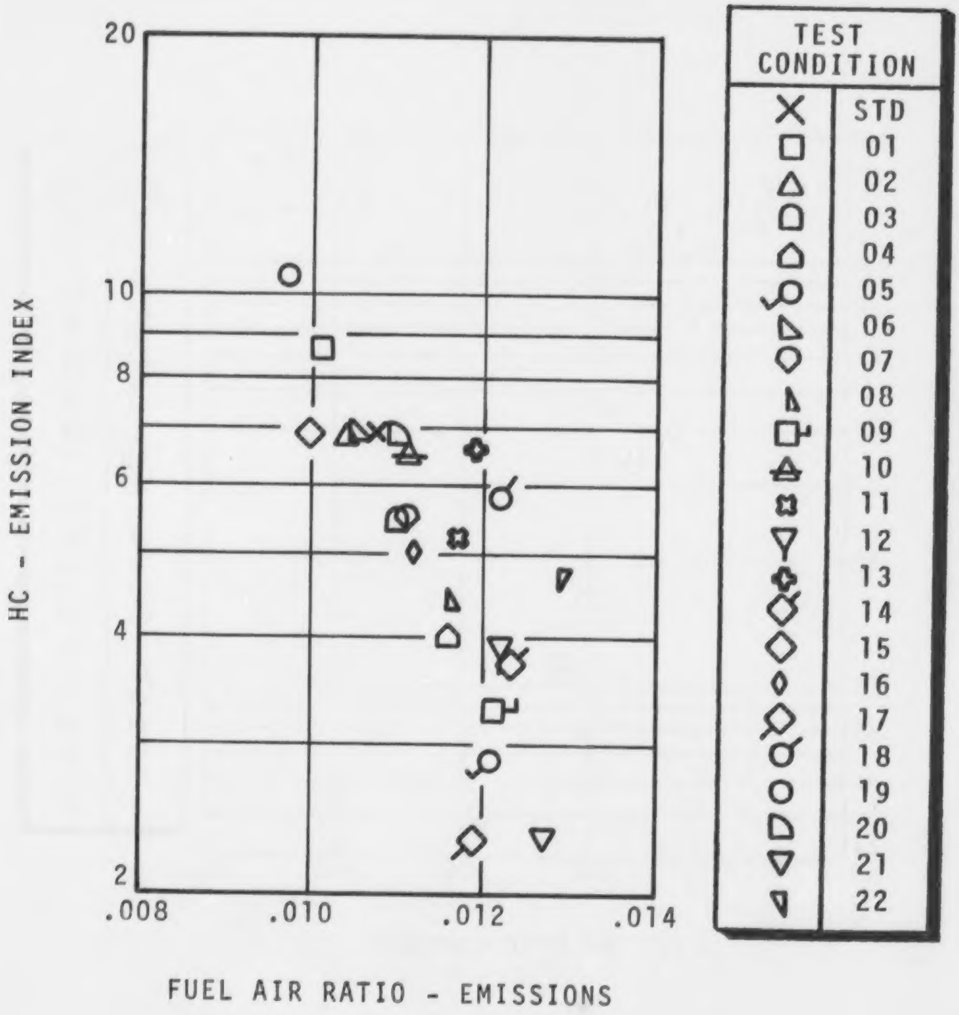


Figure 11-12. HC Emission Index Versus Fuel-Air Ratio, Rig Test - 1.5 x Idle.

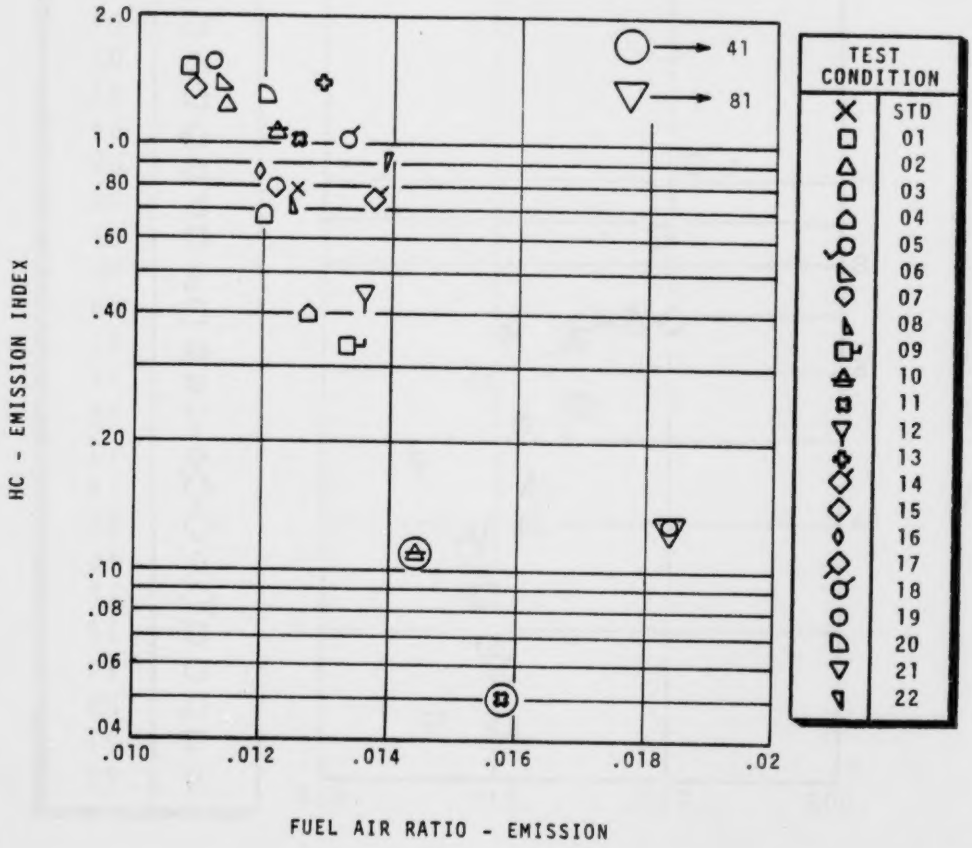


Figure 11-13. HC Emission Index Versus Fuel-Air Ratio, Rig Test - Approach.

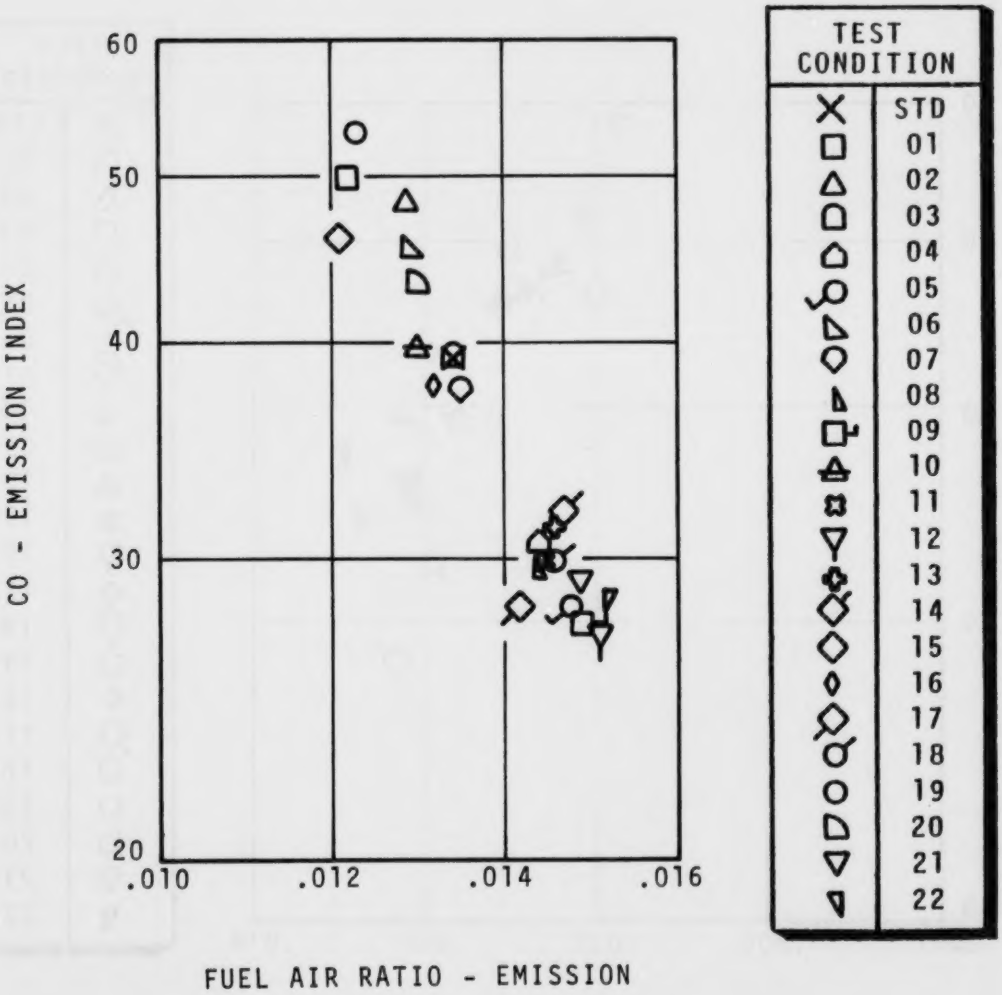


Figure 11-14. CO Emission Index Versus Fuel-Air Ratio, Rig Test - Idle.

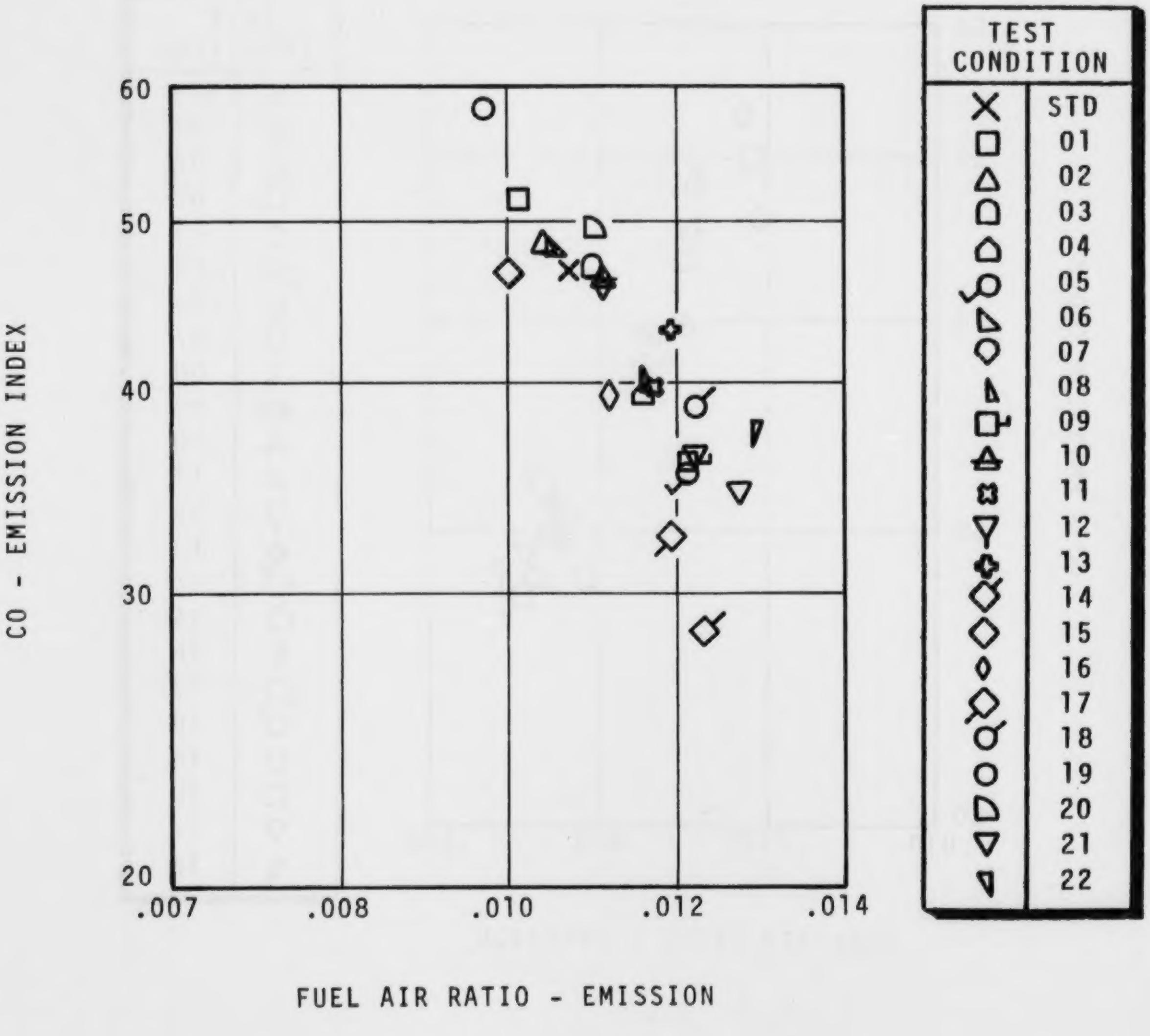


Figure 11-15. CO Emission Index Versus Fuel-Air Ratio, Rig Test - 1.5 x Idle.

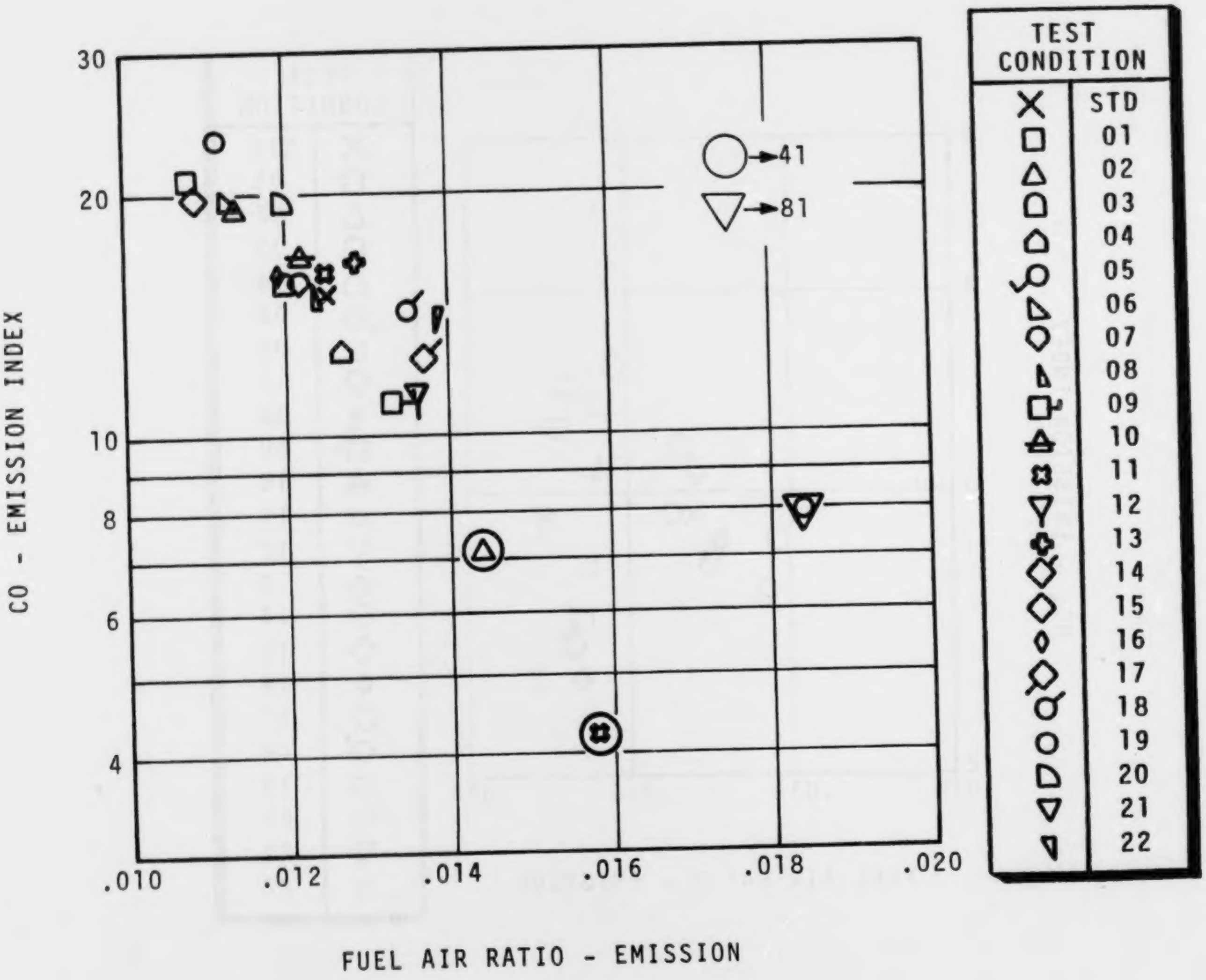


Figure 11-16. CO Emission Index Versus Fuel-Air Ratio, Rig Test - Approach.

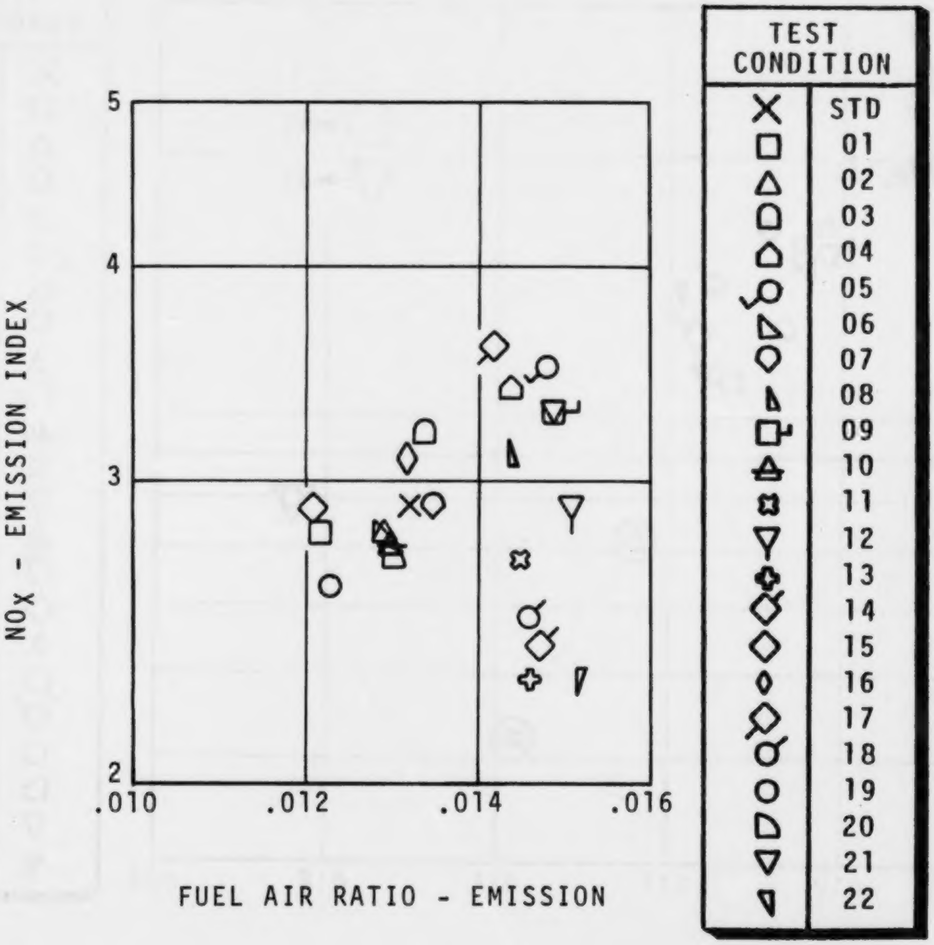


Figure 11-17. NO_x Emission Index Versus Fuel-Air Ratic, Rig Test - Idle.

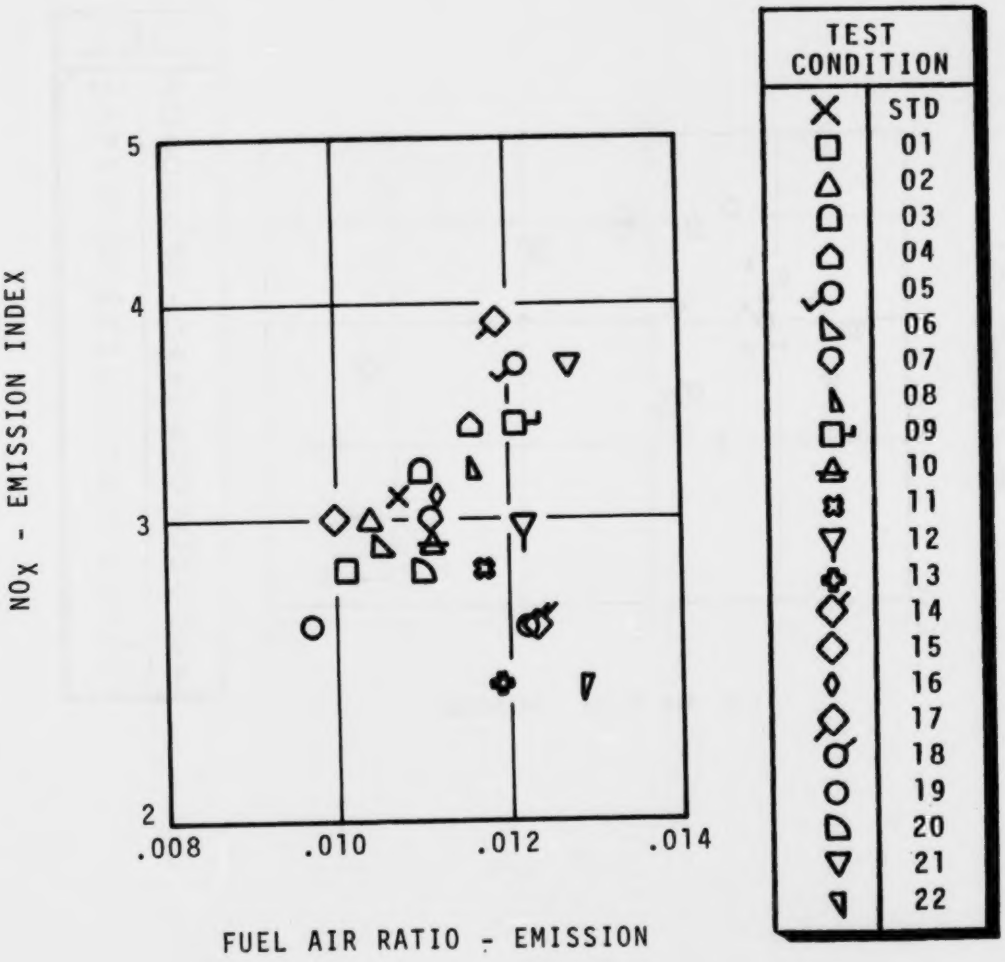


Figure 11-18. NO$_x$ Emission Index Versus Fuel-Air Ratio, Rig Test - 1.5 x Idle.

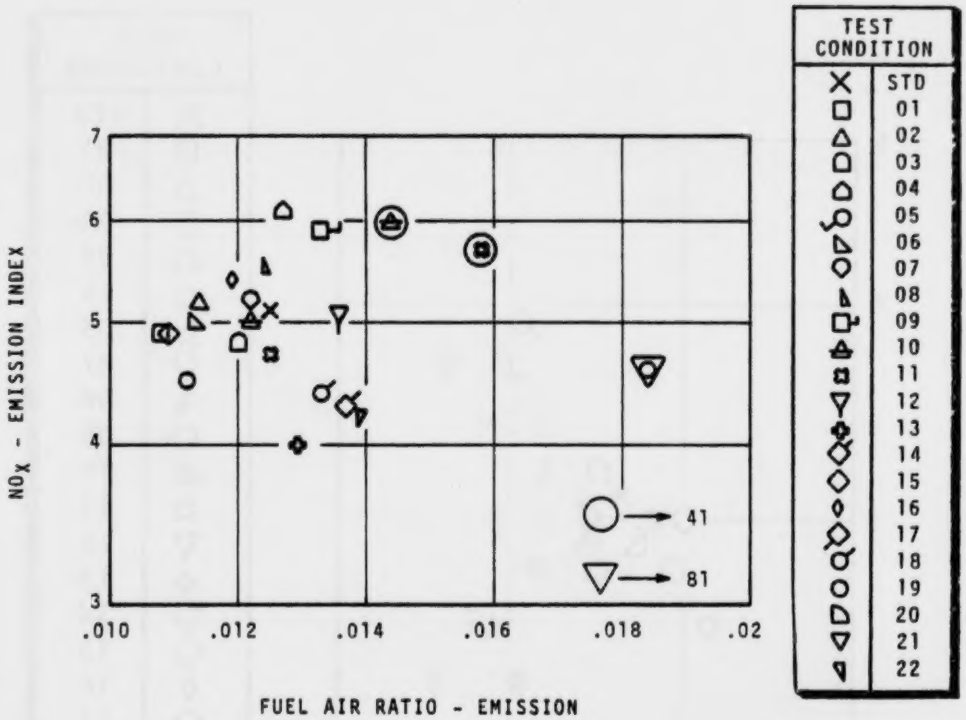


Figure 11-19. NO_x Emission Index Versus Fuel-Air Ratio, Rig Test - Approach.

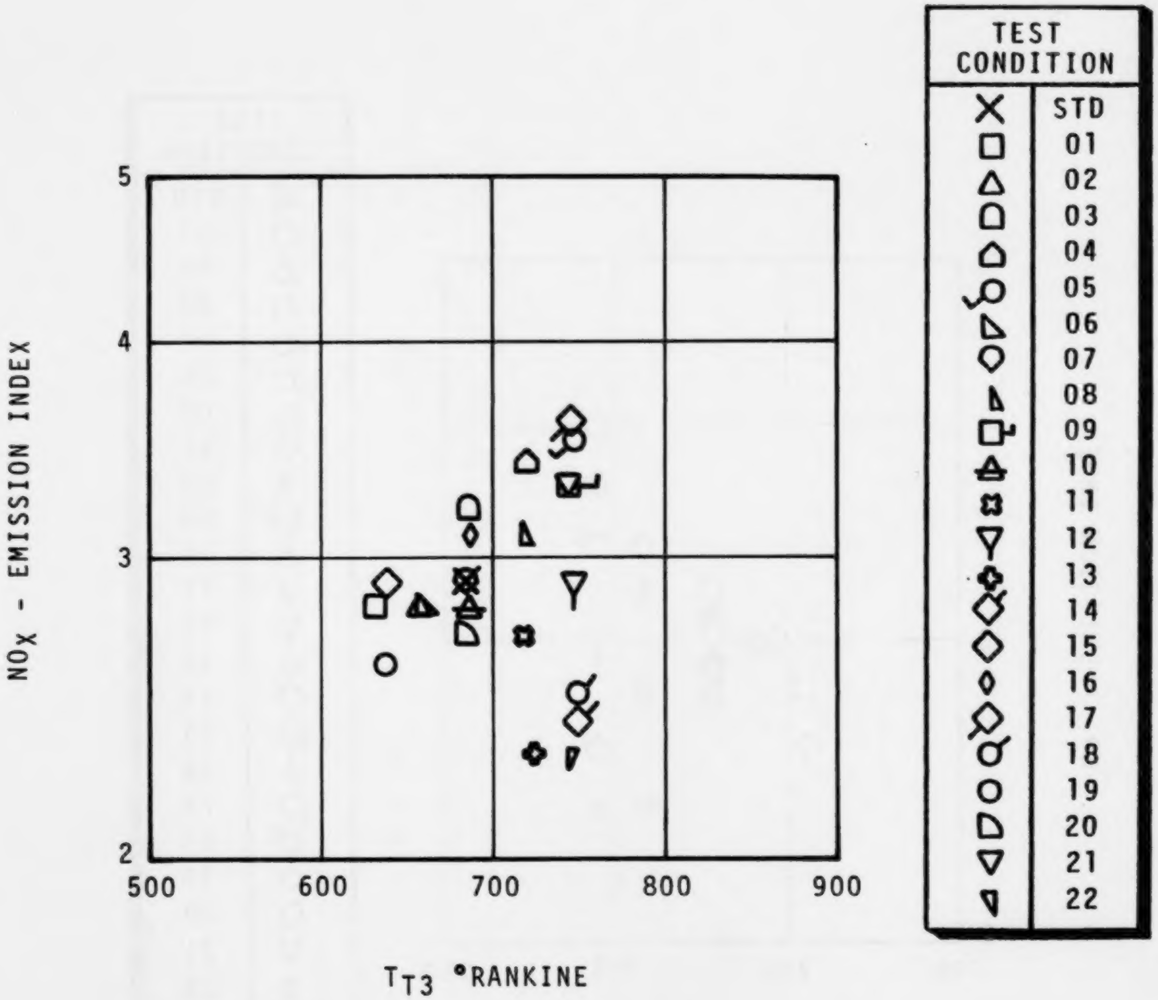


Figure 11-20. NO_x Emission Index Versus T_{t3}, Rig Test - Idle.

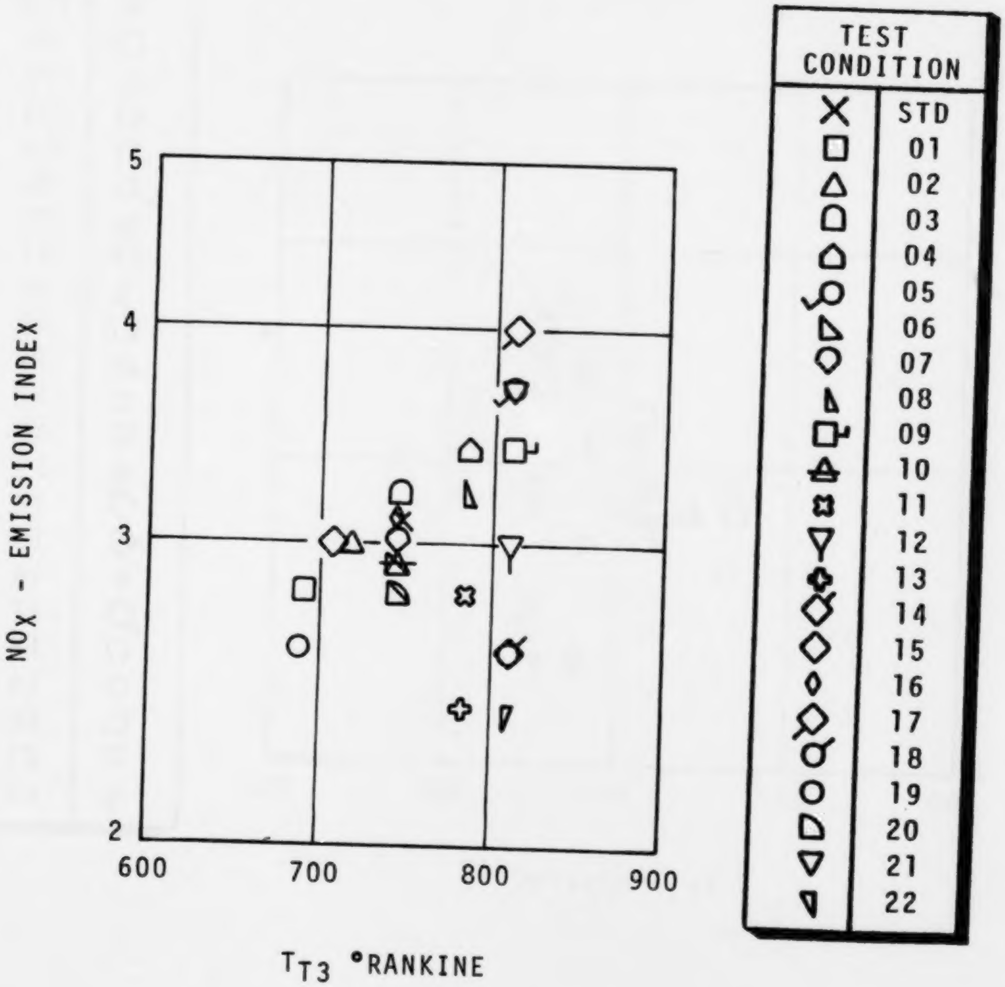


Figure 11-21. NO$_x$ Emission Index Versus T$_{t3}$, Rig Test - 1.5 x Idle.

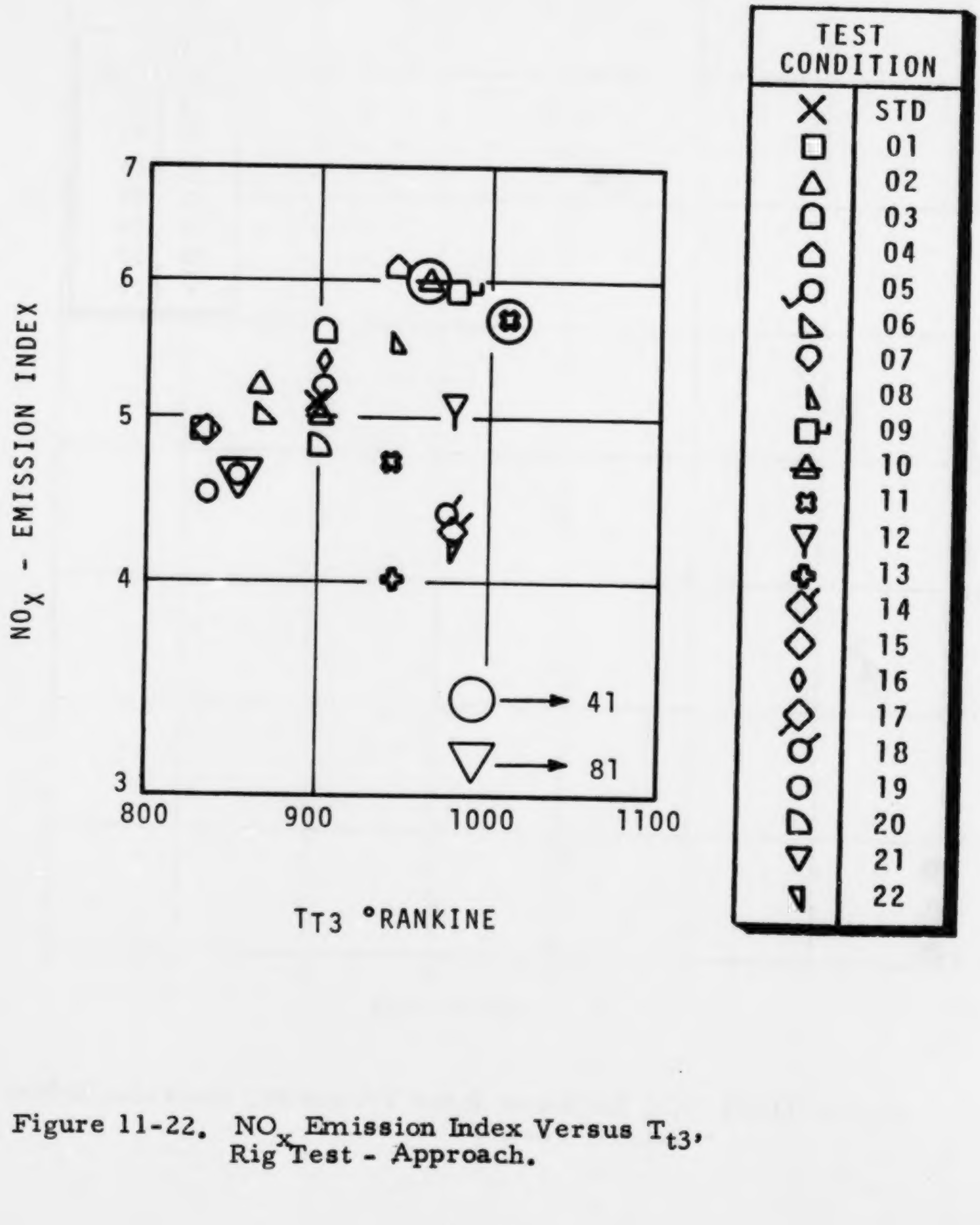


Figure 11-22. NO$_x$ Emission Index Versus T$_{t3}$, Rig Test - Approach.

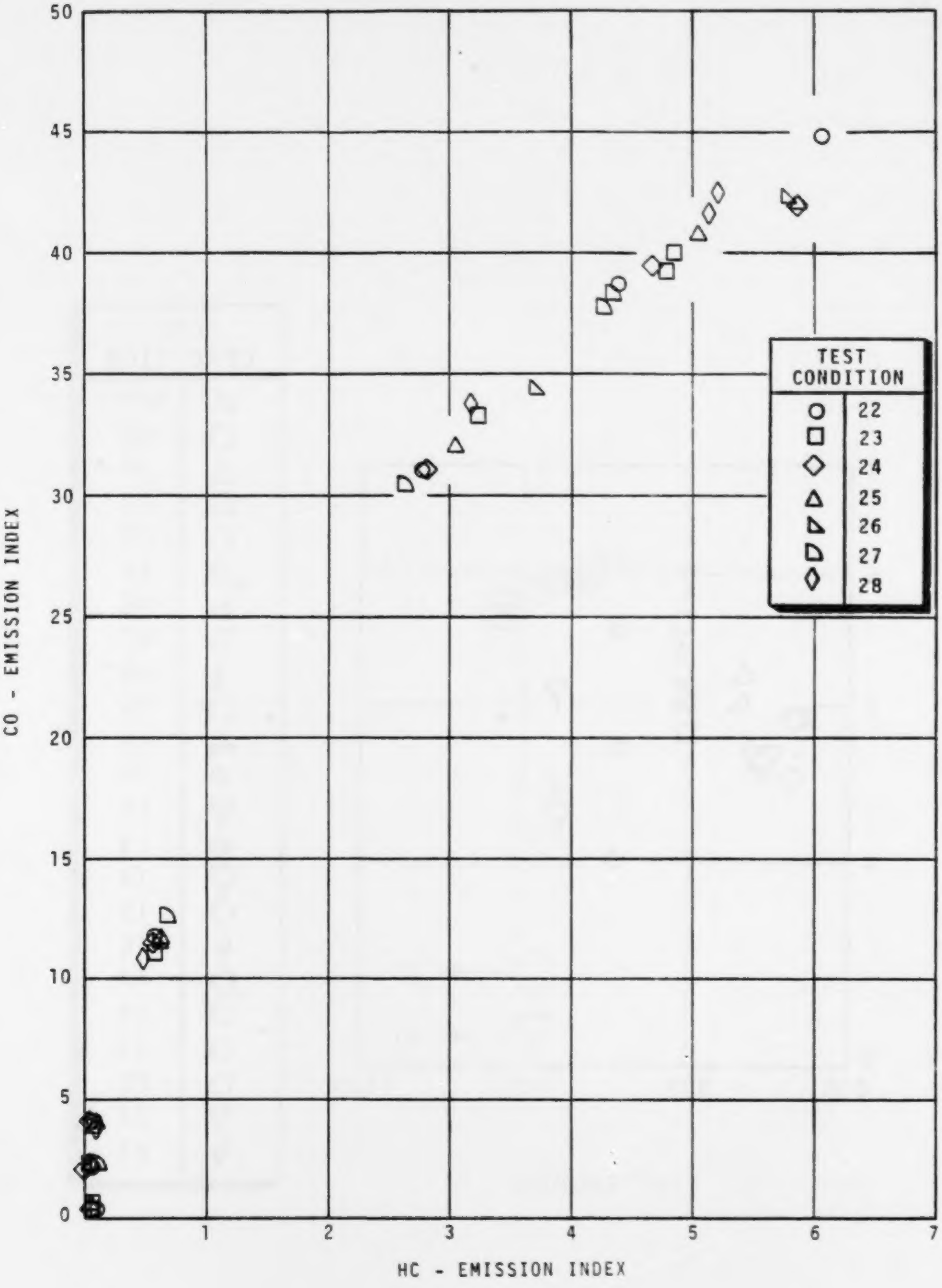


Figure 11-23. CO Emission Index Versus HC Emission Index, Engine Test.

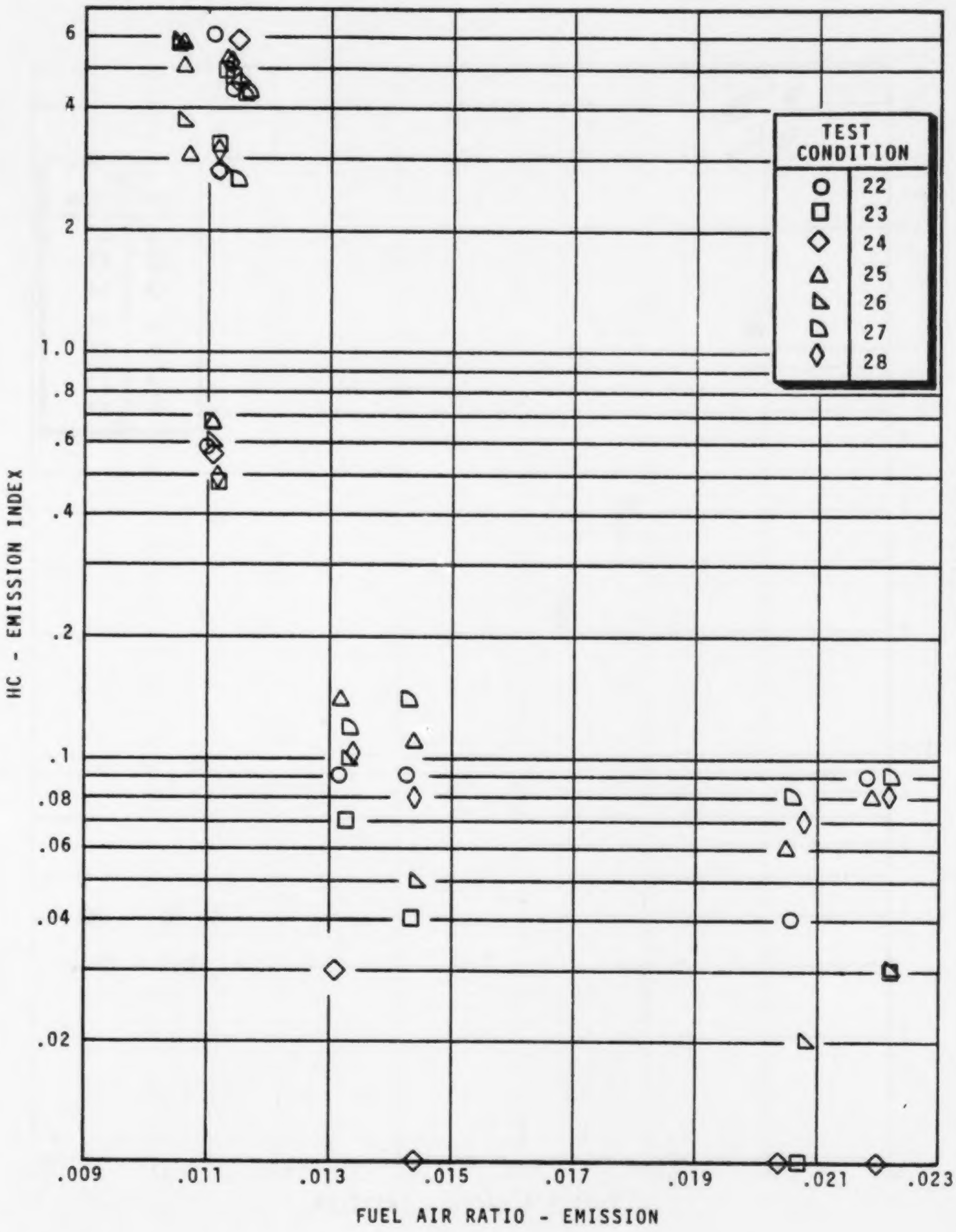


Figure 11-24. HC Emission Index Versus Fuel-Air Ratio, Engine Test.

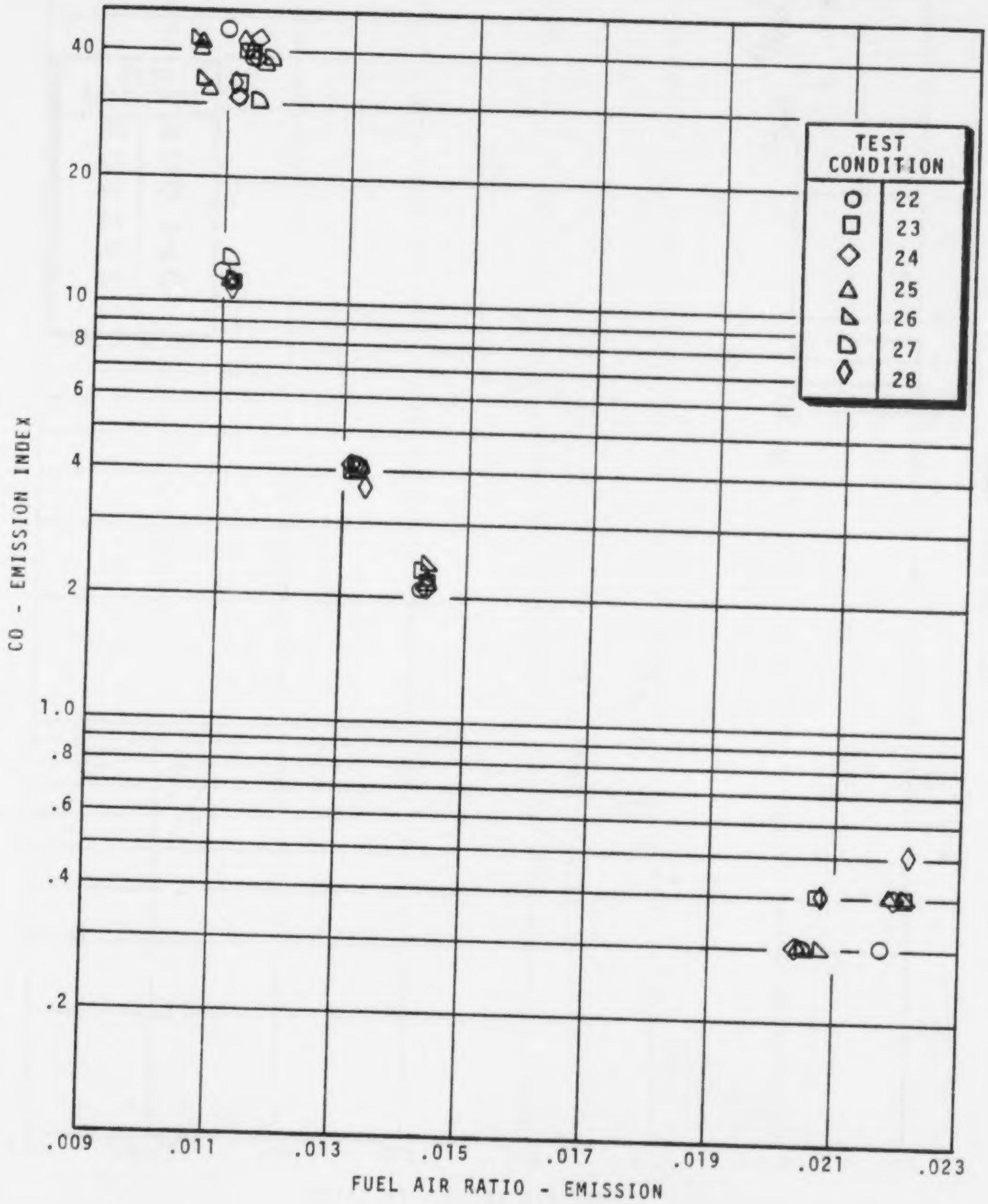


Figure 11-25. CO Emission Index Versus Fuel-Air Ratio, Engine Test.

Tn,

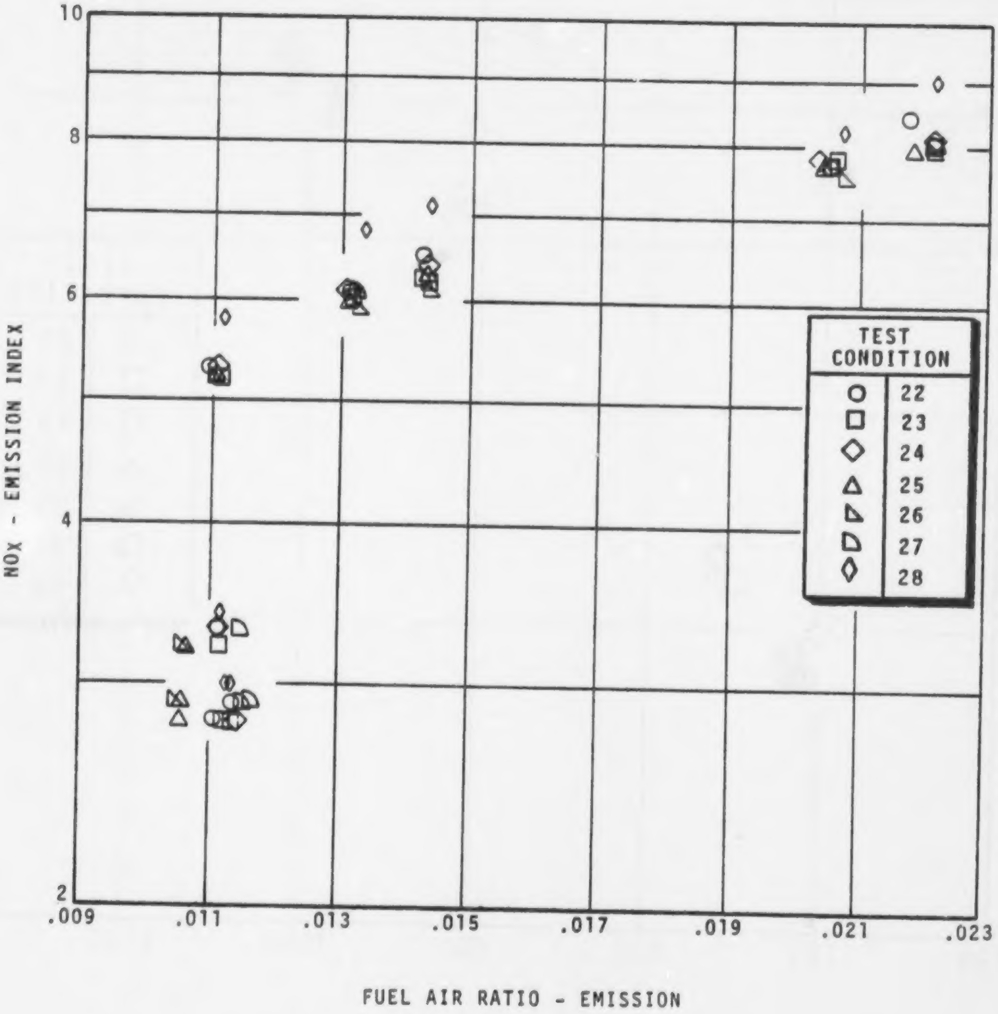


Figure 11-26. NO_x Emission Index Versus Fuel-Air Ratio, Engine Test.

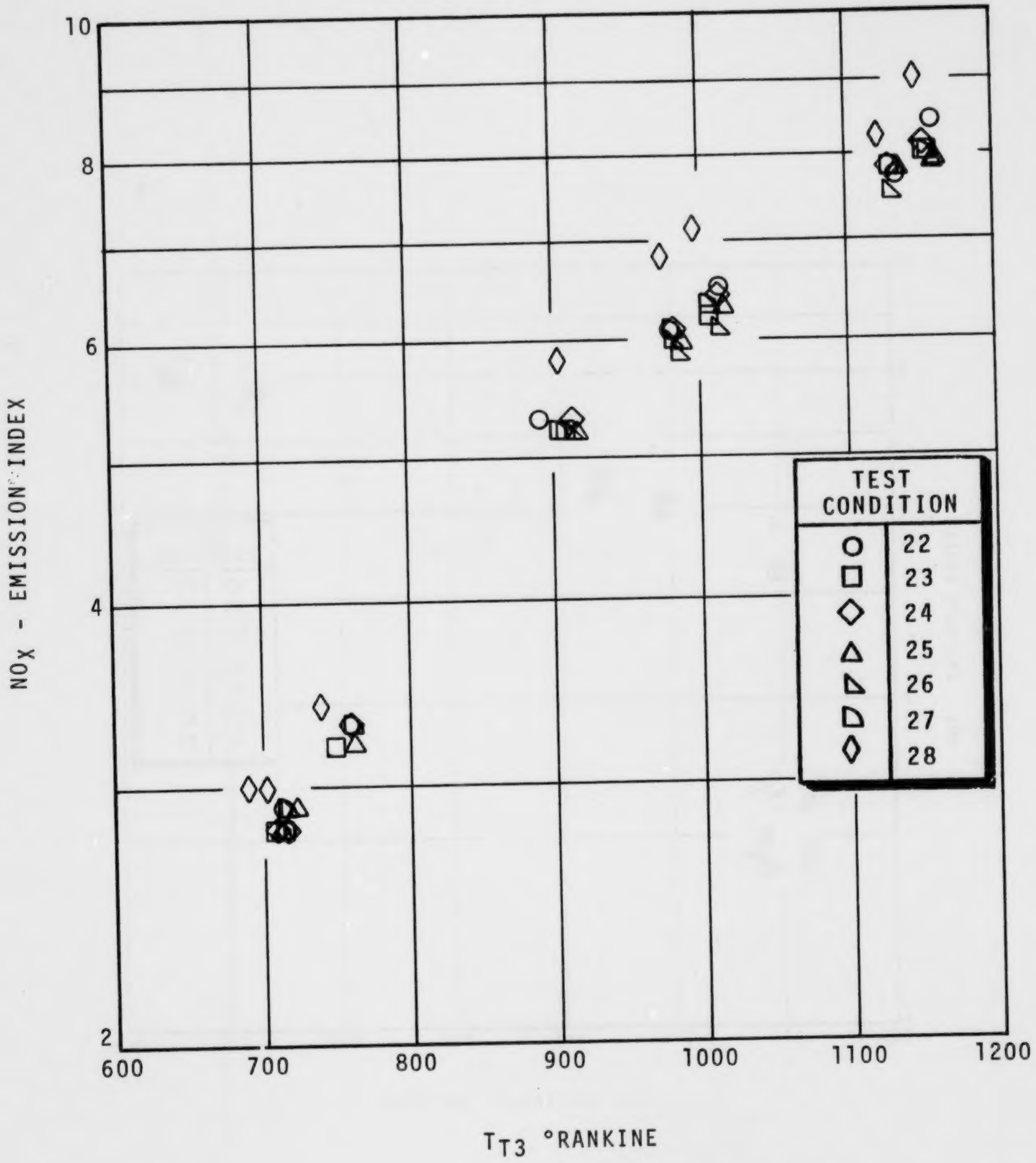


Figure 11-27. NO_x Emission Index Versus T_{t3}, Engine Test.

TA,

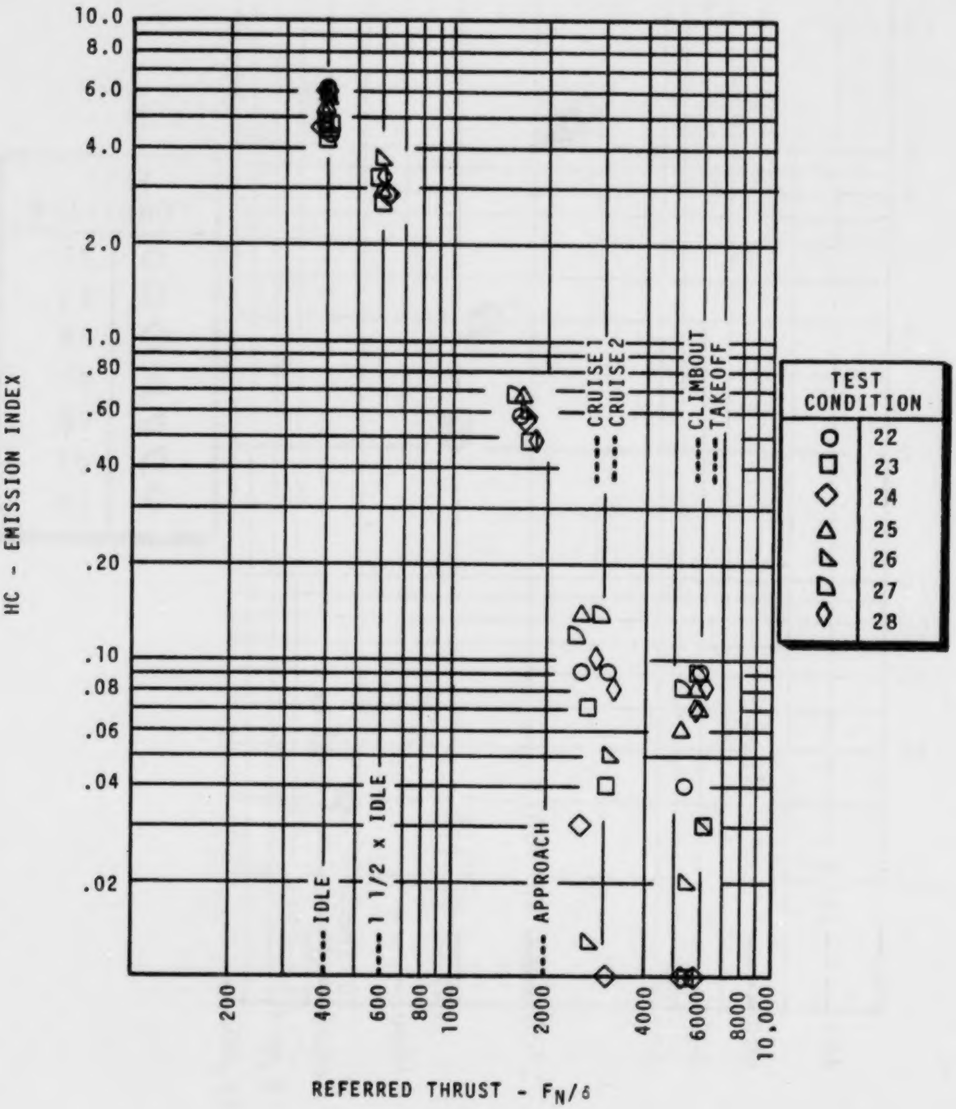


Figure 11-28. HC Emission Index Versus Referred Thrust, Engine Test.

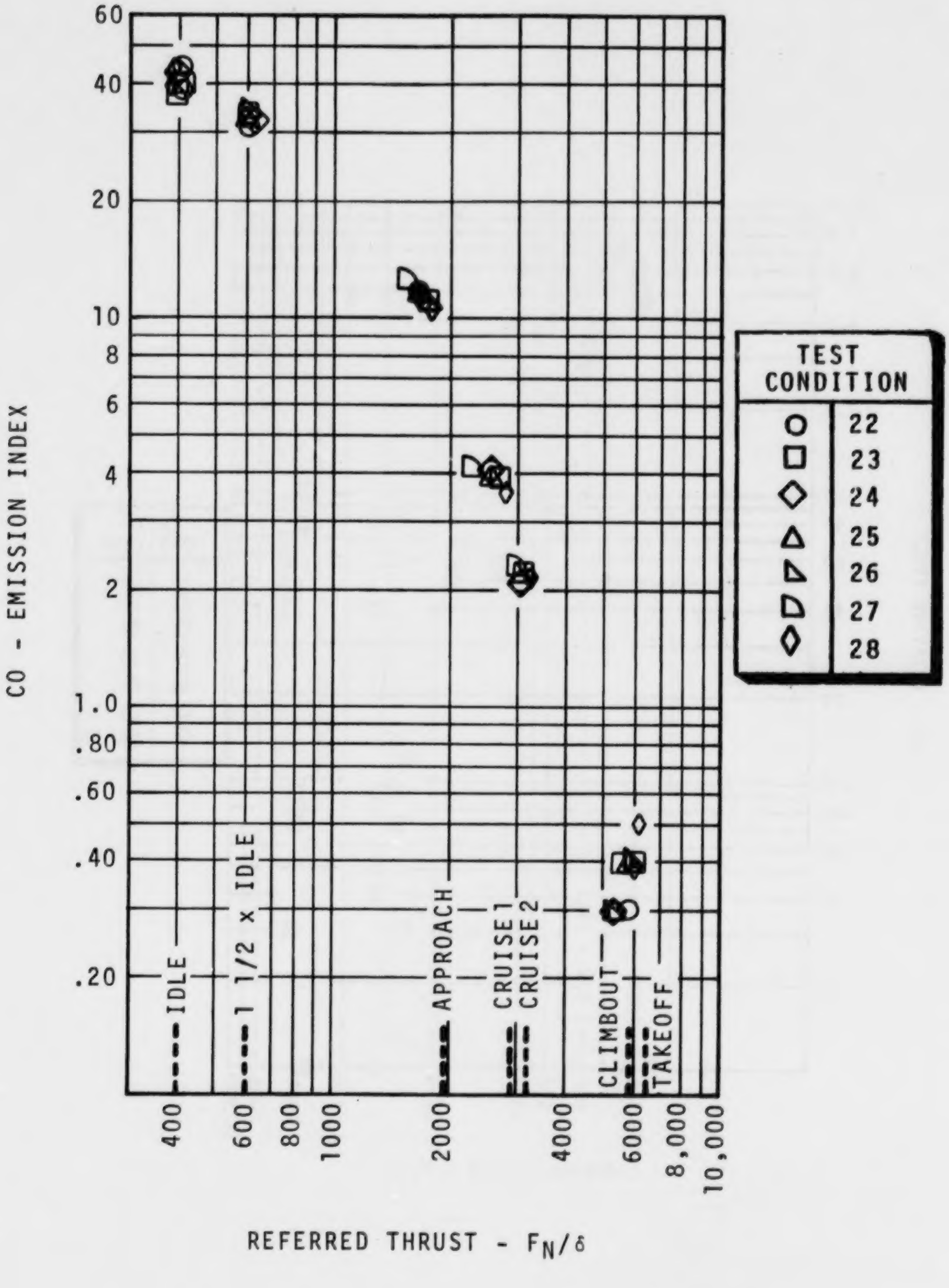


Figure 11-29. CO Emission Index Versus Referred Thrust, Engine Test.

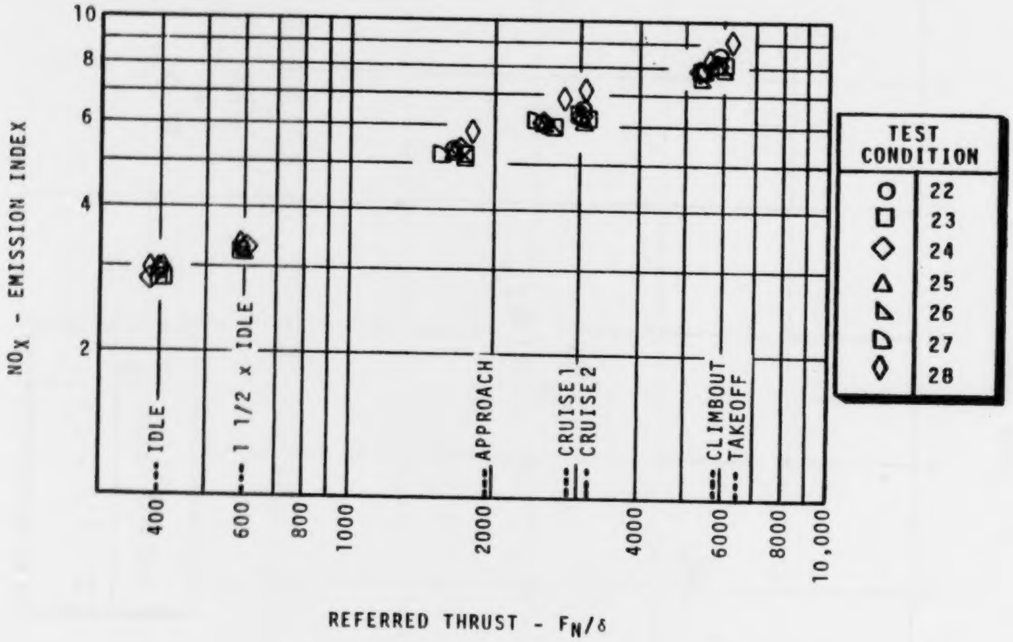


Figure 11-30. NO$_X$ Emission Index Versus Referred Thrust, Engine Test.

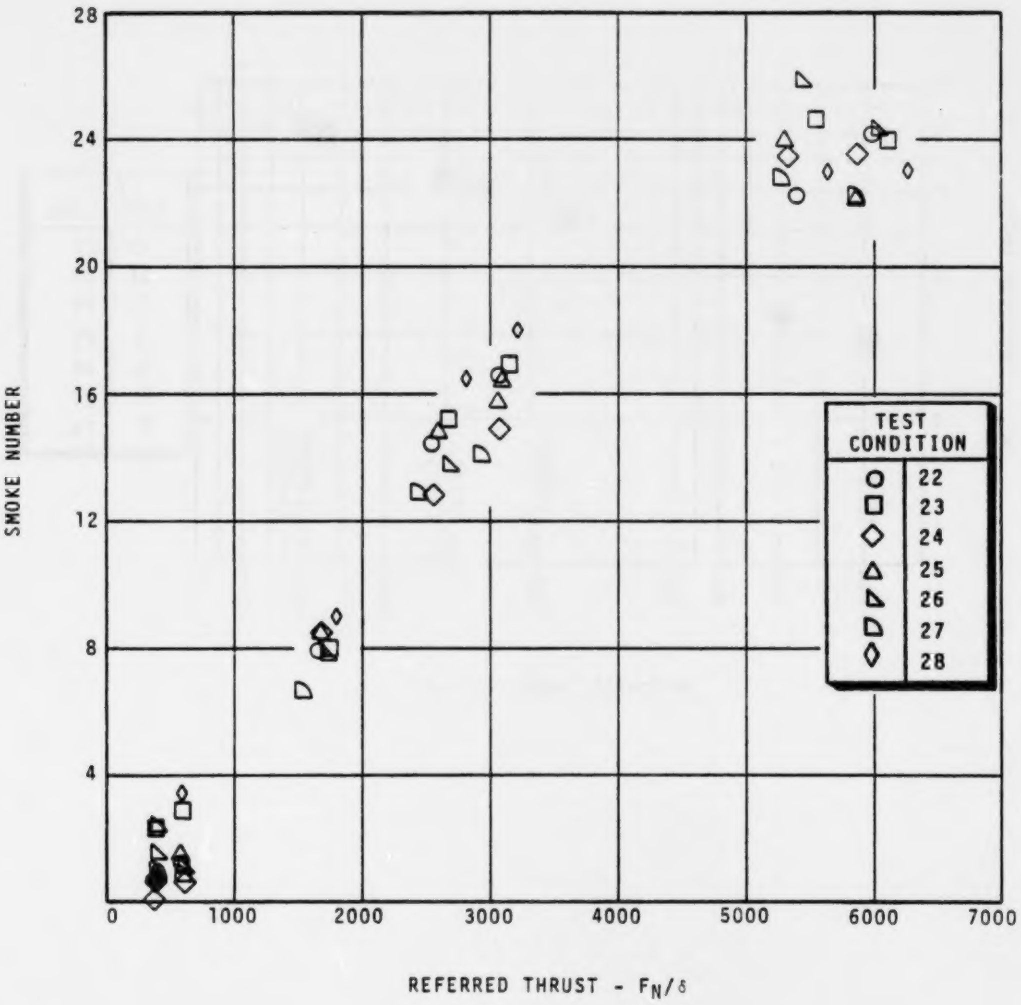


Figure 11-31. Smoke Number Versus Referred Thrust, Engine Test.

APPENDIX A
FEDERAL REGISTER CORRESPONDENCE

Appendix A includes the letter of 31 August 1976 from the EPA in response to Lycoming's letter or request for deviations from the procedures stated in Title 40, Part 87, of the Federal Register.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
ANN ARBOR, MICHIGAN 48105

August 31, 1976

OFFICE OF
AIR AND WATER PROGRAMS

RECEIVED
SEP 2 - 1976
G. B. DAVIS

Mr. A.L. Ledewitz
Contract Administrator
AVCO, Lycoming Division
550 S. Main St.
Stratford, Conn. 06497

Dear Mr. Ledewitz:

Enclosed is a response to your letter requesting deviations from the prescribed test procedure as contracted to AVCO Lycoming in Contract Number 68-03-2383 "Determination of the Effects of Ambient Conditions on Aircraft Engine Emissions by Combustor Rig Testing". This enclosure presents a response to each variance requested with a statement of acceptance or rejection for that request.

Modification to content of the contract for incorporation of these revisions, is unnecessary since these modifications are within the stated authority of the Project Officer. These revisions provided shall therefore be incorporated into the performance of this contract.

Sincerely yours,

Gary Austin, Project Officer
Standards Development and Support Branch

cc: Albert Ahlquist

Determination of the Effects of Ambient Conditions
Contract Number 68-03-2383

This memo presents a response to AVCO Lycoming's request for variance to the Scope of Work of the subject contract. The contract requires that "Emission Measurements are to be conducted utilizing the instruments and measurement procedures specified in the Federal Register of July 17, 1973, pages 19088 through 19103. It is mandatory that this procedure be completely adhered to during every test, except where variance is granted by the project officer...".

Section 87.62(a)(1) Test Procedures (propulsion engines)

AVCO request - Delete the entire subsection

Response - This sub-section may be deleted in its entirety except for the first sentence of the second paragraph. This sentence modified slightly shall read as follows; Actual power setting, that when corrected to standard day conditions, corresponds to the contracted percent of power.

Section 87.64(d) Component description (exhaust gas analytical system)

AVCO request - Delete for combustor rig testing

Response - This section shall not be deleted because it is essential in the understanding of the sample and analytical system.

Section 87.64(c)(1)(ii)(d) (axial sampling plane)

AVCO request - None

Response - AVCO did not request that this section be deleted but in reference to their request that section 87.64(d) be deleted it is clear that they were referring to this section. This section shall be deleted.

Section 87.67(a) Sampling Procedures

AVCO request - Modify Sub-section (a)(1) through (4) as follows:

A "series of measurements" encompasses the testing made on a single test item (engine or combustor) in each separate installation. However, many of the listed checks will be made more often than once each series. The frequency of the checks to be run under this Paragraph, No. 87.67, will be as follows while testing.

(a) (1) Daily
(a) (2) Daily
(a) (3) Hourly
(a) (4) Hourly

Response - Rather than respond directly to the AVCO request the sub-section has been rewritten for this combustor rig test as follows.

Section 87.67(a)

(1) Check the sampling system for any leaks that could dilute the exhaust gas. Replace or clean sample line filters daily or more frequently if necessary to insure the integrity of the sample.

(2) Zero and Span Check.

(i) Introduce the zero grade gas at the same flow rate used to analyze the test samples and zero the analyzers. Obtain a stable reading on each amplifier meter and recorder. Record Readings.

(ii) Introduce span gases and set the CO and CO_2 analyzer gains, the HC analyzer sample capillary flow rate and electronic gain control, if provided, and the NOx analyzer high voltage supply or amplifier gain to match the calibration curves. In order to avoid corrections, span and calibrate at the same flow rates used to analyze the test samples. Span gases should have concentrations equal to approximately 80 percent of each range used. If the gain has shifted significantly on the CO or CO_2 analyzers, check tuning. If necessary, check the calibration. Show actual concentrations on chart. Log the gain readings. Record reading.

(3) If the zero or span of subparagraph (2) has shifted re-zero and then re-span analyzers. Record new readings. Upon completion of the re-span check zero.

(4) Zero and Span check of subparagraph (2) and (3) shall be performed at the end of the test but not less than once per hour.

Section 87.67(a) Sample Procedures

AVCO request - Sub-section (a)(5)

Change "2 seconds" to "approximately 10 seconds". Add "Residence time in sample line, between sample probe and emissions data acquisition system cabinet, must be under 2 seconds as computed by line length, diameter, and measured flow".

Response - This section is in the process of being modified through Technical Amendment to the aircraft emission regulations. The modified procedure shall be used in place of the present section. This procedure is:

(5) Check the sample system line temperature. Also check the emission measurement system response time using the following procedure:

(i) In addition to the requirements or paragraph 87.64, the sample system transport time shall be rechecked each time the emission measurement system is modified in any manner which may reasonably be expected to change the sample system transport time.

(ii) The emission measurement system response time shall be checked. Introduce an HC span gas at the sample probe and measure the time it takes for the instrument to respond to 15% of span concentration. The emission measurement system response time shall be 7 seconds or less.

(iii) Repeat (ii) for the CO, CO_2, and NOx instrumentation. The emission measurement system response time for these instruments shall be 7 seconds or less except for the NOx, chemiluminescence, instrument which shall have a response time of 9 seconds or less.

(iv) The results of (ii) and (iii) must compare with the emission measurement system response times of the previous test within ± 1.0 second.

Section 87.67(a) Sample Procedures

AVCO request - Subsection (a)(6) & (10)

(6) Continuous Monitor
(10) Hourly

Response - Both of these requests follow the requirement of the federal regulations and the testing requirements of this program and are therefore acceptable.

Section 87.67(b)(2) Sample line contamination

AVCO request - Change: "Check sample line for contamination each time the instrument zero and span points are checked" is to read "Check sample line for excessive contamination before, and after, each series of measurements".

Response - The sentence of concern shall be modified to read as follows "Check sample line for contamination before, and after, each series of measurements". All other parts of the section shall remain the same.

APPENDIX B

COMBUSTOR DATA

```
COMBUSTOR RIG TEST
DATE                                                                      001145
 1/18/77                      DATA POINT             TEST CELL            001145
                              001145                 1                    001145
INSTRUMENT OPERATOR                                  TEST OPERATOR        001145
TREMBLEY                                             EHARDT               001145
ENGINE MANUFACTURER           MODEL                  SERIAL NUMBER        001145
LYCOMING                      ALF-502                LF04                 001145
FUEL IDENT.                   FUEL FLOW PPH          MANIFOLD FUEL TEMP FAH 001145
JET-A HC RATIO 0.160           349.                  224.7                001145
ORIFICE AIRFLOW LB/SEC        PT3 PSIA               TT3 DEG.RANKINE      001145
  7.3                          35.2                  684.2                001145
SIMULATED THRUST LBS          FUEL-AIR RATIO MEAS.                        001145
 400.0                        0.0133                                      001145
SIMULATED INLET PRESSURE PO PSIA                                          001145
14.696                                                                    001145
SIMULATED INLET TEMPERATURE TO DEG.RANKINE                                001145
518.7                                                                     001145
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                       001145
 42.3                                                                     001145
FILTER AREA .385 SI                                                       001145
CLEAN CK SMOKE NUMBER 0                                                   001145
SMOKE NUMBER       VOL.-LITERS    FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH     001145
      2.3                3.0         0.48     11.270              75.0    001145
      2.3                4.0         0.48     11.270              75.0    001145
      2.3                7.0         0.48     11.270              75.0    001145
      4.5               11.0         0.48     11.270              75.0    001145
GASEOUS EMISSIONS                                                         001145
                  FID       NDIR       NDIR       CHEMI      CHEMI        001145
                  UHC       CO         CO2        NO         NOX          001145
RANGE              2         2          2          1          1           001145
INSTR GAS TEMP    153.      62.        62.        64.        64.          001145
RAW VALUE MV       15.4    1005.2      590.6      550.6     1007.1        001145
GAS CONCEN PPM(C)  150.4     538.8    26860.5       13.4       24.5       001145
GAS CONCEN PCT    0.0150    0.0539     2.6860     0.0013     0.0024       001145
EMISSION INDEX     5.46      39.3      3080.        1.6        2.5        001145
FUEL-AIR RATIO    0.0134                                                  001145
                                                                          001145
```

```
COMBUSTOR RIG TEST                                                              002145
DATE                         DATA POINT             TEST CELL                   002145
 1/20/77                     002145                 1                           002145
INSTRUMENT OPERATOR                                 TEST OPERATOR               002145
TREMBLEY                                            EHARDT                      002145
ENGINE MANUFACTURER          MODEL                  SERIAL NUMBER               002145
LYCOMING                     ALF-502                LF04                        002145
FUEL IDENT.                  FUEL FLOW PPH          MANIFOLD FUEL TEMP FAH      002145
JET-A HC RATIO 0.160          416.                  225.9                       002145
ORIFICE AIRFLOW LB/SEC       PT3 PSIA               TT3 DEG.RANKINE             002145
 10.7                         40.2                  745.9                       002145
SIMULATED THRUST LBS         FUEL-AIR RATIO MEAS.                               002145
 600.0                       0.0108                                             002145
SIMULATED INLET PRESSURE PO PSIA                                                002145
14.696                                                                          002145
SIMULATED INLET TEMPERATURE TO DEG.RANKINE                                      002145
518.7                                                                           002145
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                             002145
 44.0                                                                           002145
FILTER AREA .385 SI                                                             002145
CLEAN CK SMOKE NUMBER 0                                                         002145
SMOKE NUMBER          VOL.-LITERS     FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH       002145
          2.3                  3.0        0.50      11.270           76.0       002145
          2.3                  4.0        0.50      11.270           76.0       002145
          2.3                  7.0        0.50      11.320           77.0       002145
          4.5                 11.0        0.50      11.370           77.0       002145
GASEOUS EMISSIONS                                                               002145
                     FID         NDIR        NDIR        CHEMI      CHEMI       002145
                     UHC         CO          CO2         NO         NOX         002145
RANGE                 2           3           2           1          1          002145
INSTR GAS TEMP       153.        56.         56.         64.        64.         002145
RAW VALUE MV          19.4       408.1       483.7       450.6      508.4       002145
GAS CONCEN PPM(C)     152.1       508.0       21259.7       10.3       20.8     002145
GAS CONCEN PCT       0.0152      0.0508      2.1260      0.0010     0.0021      002145
EMISSION INDEX        6.54        46.6       3063.          1.5        3.1      002145
FUEL-AIR RATIO       0.0107                                                     002145
```

```
COMBUSTOR RIG TEST
DATE                                                                   003144
 1/20/77                  DATA POINT           TEST CELL               003144
INSTRUMENT OPERATOR.      003144               1                       003144
TREMBLEY                                       TEST OPERATOR           003144
ENGINE MANUFACTURER                            EHARDT                  003144
LYCOMING                  MODEL                SERIAL NUMBER           003144
FUEL IDENT.               ALF-502              LF04                    003144
JET-A HC RATIO 0.160      FUEL FLOW PPH        MANIFOLD FUEL TEMP FAH  003144
ORIFICE AIRFLOW LB/SEC     804.                227.4                   003144
 17.5                     PT3 PSIA             TT3 DEG.RANKINE         003144
SIMULATED THRUST LBS       75.2                898.5                   003144
1950.0                    FUEL-AIR RATIO MEAS.                         003144
SIMULATED INLET PRESSURE P0 PSIA                                       003144
14.696                                                                 003144
SIMULATED INLET TEMPERATURE T0 DEG.RANKINE                             003144
518.7                                                                  003144
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                    003144
 44.9                                                                  003144
FILTER AREA .385 SI                                                    003144
CLEAN CK SMOKE NUMBER 0                                                003144
SMOKE NUMBER          VOL.-LITERS     FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH  003144
      10.9                   3.0          0.60     11.170           77.0  003144
       6.7                   4.0          0.52     11.370           77.0  003144
      10.9                   7.0          0.52     11.370           77.0  003144
      14.9                  11.0          0.53     11.370           78.0  003144
GASEOUS EMISSIONS                                                      003144
                     FID        NDIR        NDIR        CHEMI      CHEMI   003144
                     UHC        CO          CO2         NO         NOX     003144
RANGE                 1          2           2           2          2      003144
INSTR GAS TEMP       153.       59.         59.         64.        64.     003144
RAW VALUE MV         25.7       437.9       560.6       338.1      434.8   003144
GAS CONCEN PPM(C)     19.9       191.2       25438.3       31.0       40.0 003144
GAS CONCEN PCT       0.0020     0.0191      2.5438      0.0031     0.0040  003144
EMISSION INDEX        0.78       15.0       3133.          4.0        5.1  003144
FUEL-AIR RATIO       0.0125                                                003144
                                                                       003144
```

```
COMBUSTOR RIG TEST                                                                        191135
DATE                         DATA POINT            TEST CELL                              191135
 2/ 1/77                     191135                1                                      191135
INSTRUMENT OPERATOR                                TEST OPERATOR                          191135
TREMBLEY                                           EHARDT                                 191135
ENGINE MANUFACTURER          MODEL                 SERIAL NUMBER                          191135
LYCOMING                     ALF-502               LF04                                   191135
FUEL IDENT.                  FUEL FLOW PPH         MANIFOLD FUEL TEMP FAH                 191135
JET-A HC RATIO 0.158          285.                 226.5                                  191135
ORIFICE AIRFLOW LB/SEC       PT3 PSIA              TT3 DEG.RANKINE                        191135
  6.5                         30.6                 637.0                                  191135
SIMULATED THRUST LBS         FUEL-AIR RATIO MEAS.                                         191135
 400.0                       0.0122                                                       191135
SIMULATED INLET PRESSURE P0 PSIA                                                          191135
12.761                                                                                    191135
SIMULATED INLET TEMPERATURE T0 DEG.RANKINE                                                191135
478.7                                                                                     191135
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                                       191135
 24.9                                                                                     191135
FILTER AREA .385 SI                                                                       191135
CLEAN CK SMOKE NUMBER 0                                                                   191135
SMOKE NUMBER          VOL.-LITERS      FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH                191135
           2.3                3.0          0.50     11.358              76.0              191135
           0.0                4.0          0.50     11.382              76.0              191135
           0.0                7.0          0.50     11.333              75.0              191135
           6.7               11.0          0.50     11.333              75.0              191135
GASEOUS EMISSIONS                                                                         191135
                  FID        NDIR        NDIR        CHEMI       CHEMI                    191135
                  UHC         CO          CO2         NO          NOX                     191135
RANGE              2          3           2           1           1                       191135
INSTR GAS TEMP    153.       59.         59.         64.         64.                      191135
RAW VALUE MV       22.6      486.3       551.3       399.5       807.1                    191135
GAS CONCEN PPM(C)  265.0      667.2       24403.5        9.6        19.5                  191135
GAS CONCEN PCT    0.0265     0.0667      2.4404      0.0010      0.0020                   191135
EMISSION INDEX    10.46       53.0       3048.          1.3         2.6                   191135
FUEL-AIR RATIO    0.0123                                                                  191135
```

```
COMBUSTOR RIG TEST
DATE                                                                           011135
 3/ 3/77                         DATA POINT         TEST CELL                  011135
INSTRUMENT OPERATOR              011135             1                          011135
TREMBLEY                                            TEST OPERATOR              011135
ENGINE MANUFACTURER                                 EHARDT                     011135
LYCOMING                         MODEL              SERIAL NUMBER              011135
FUEL IDENT.                      ALF-502            LF04                       011135
JET-A HC RATIO 0.158             FUEL FLOW PPH      MANIFOLD FUEL TEMP FAH     011135
ORIFICE AIRFLOW LB/SEC            330.              226.7                      011135
  7.5                            PT3 PSIA           TT3 DEG.RANKINE            011135
SIMULATED THRUST LBS              35.1              632.5                      011135
 400.0                           FUEL-AIR RATIO MEAS.                          011135
SIMULATED INLET PRESSURE PC PSIA 0.0122                                        011135
14.696                                                                         011135
SIMULATED INLET TEMPERATURE TC DEG.RANKINE                                     011135
478.7                                                                          011135
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                            011135
 24.7                                                                          011135
FILTER AREA .385 SI                                                            011135
CLEAN CK SMOKE NUMBER 0                                                        011135
SMOKE NUMBER          VOL.-LITERS      FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH     011135
      0.0                    3.0           0.50      11.422                    011135
      4.5                    4.0           0.50      11.422           77.0     011135
      6.7                    7.0           0.50      11.422           77.0     011135
      6.7                   11.0           0.50      11.471           77.0     011135
GASEOUS EMISSIONS                                                     77.0     011135
                       FID          NDIR         NDIR         CHEMI            011135
                       UHC          CO           CO2          NO      CHEMI    011135
RANGE                   2            3            2           NO       NOX     011135
INSTR GAS TEMP         154.         66.           2           1        1       011135
RAW VALUE MV            28.2        467.2        66.          64.      65.     011135
GAS CONCEN PPM(C)       246.3        618.8       549.3        388.7   664.8    011135
GAS CONCEN PCT         0.0246       0.0619        24226.3        9.2     21.0  011135
EMISSION INDEX          9.81         49.7        2.4226       0.0009  0.0021   011135
FUEL-AIR RATIO         0.0122                    3055.           1.2     2.8   011135
                                                                               011135
```

```
COMBUSTOR RIG TEST                                                           151135
DATE                         DATA POINT          TEST CELL                   151135
 3/ 3/77                     151135              1                           151135
INSTRUMENT OPERATOR                              TEST OPERATOR               151135
TREMBLEY                                         EFARCT                      151135
ENGINE MANUFACTURER          MODEL               SERIAL NUMBER               151135
LYCOMING                     ALF-502             LF04                        151135
FUEL IDENT.                  FUEL FLOW PPH       MANIFOLD FUEL TEMP FAH      151135
JET-A HC RATIO 0.158          355.               226.8                       151135
ORIFICE AIRFLOW LB/SEC       PT3 PSIA            TT3 DEG.RANKINE             151135
  8.1                         37.9               638.5                       151135
SIMULATED THRUST LBS         FUEL-AIR RATIO MEAS.                            151135
 400.0                       0.0121                                          151135
SIMULATED INLET PRESSURE PC PSIA                                             151135
15.855                                                                       151135
SIMULATED INLET TEMPERATURE TC DEG.RANKINE                                   151135
478.7                                                                        151135
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                          151135
 24.9                                                                        151135
FILTER AREA .385 SI                                                          151135
CLEAN CK SMOKE NUMBER 0                                                      151135
SMOKE NUMBER          VOL.-LITERS     FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH    151135
       0.0                    3.0          0.50   11.423              76.0   151135
       2.3                    4.0          0.50   11.472              76.0   151135
       4.5                    7.0          0.50   11.472              76.0   151135
      12.9                   11.0          0.50   11.472              76.0   151135
GASEOUS EMISSIONS                                                            151135
                      FID         NDIR        NDIR        CHEMI      CHEMI   151135
                      UHC          CO          CO2         NO         NOX    151135
RANGE                  2           3           2           1          1      151135
INSTR GAS TEMP        154.        53.         53.         64.        64.     151135
RAW VALUE MV           24.2      442.5       548.6       402.0      531.4    151135
GAS CONCEN PPM(C)     211.3       571.0     24195.1        9.5        22.2   151135
GAS CONCEN PCT        0.0211      0.0571      2.4195      0.0010     0.0022  151135
EMISSION INDEX         8.46       46.0      3065.          1.3        2.9    151135
FUEL-AIR RATIO        0.0121                                                 151135
```

```
COMBUSTOR RIG TEST                                                                  021135
DATE                         DATA POINT            TEST CELL                        021135
 1/20/77                     021135                1                                021135
INSTRUMENT OPERATOR                                TEST OPERATOR                    021135
TREMBLEY                                           EHARDT                           021135
ENGINE MANUFACTURER          MODEL                 SERIAL NUMBER                    021135
LYCOMING                     ALF-502               LF04                             021135
FUEL IDENT.                  FUEL FLOW PPH         MANIFOLD FUEL TEMP FAH           021135
JET-A HC RATIO 0.160          339.                 225.5                            021135
ORIFICE AIRFLOW LB/SEC       PT3 PSIA              TT3 DEG.RANKINE                  021135
  7.4                         35.1                 658.8                            021135
SIMULATED THRUST LBS         FUEL-AIR RATIO MEAS.                                   021135
 400.0                       0.0127                                                 021135
SIMULATED INLET PRESSURE PO PSIA                                                    021135
14.696                                                                              021135
SIMULATED INLET TEMPERATURE TO DEG.RANKINE                                          021135
498.7                                                                               021135
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                                 021135
 24.9                                                                               021135
FILTER AREA .385 SI                                                                 021135
CLEAN CK SMOKE NUMBER 0                                                             021135
SMOKE NUMBER          VOL.-LITERS     FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH           021135
         2.3                 3.0          0.50    11.360              74.0          021135
         2.3                 4.0          0.50    11.310              74.0          021135
         2.3                 7.0          0.52    11.360              74.0          021135
         4.5                11.0          0.50    11.360              75.0          021135
GASEOUS EMISSIONS                                                                   021135
                    FID         NDIR         NDIR        CHEMI      CHEMI           021135
                    UHC         CO           CO2         NO         NOX             021135
RANGE               2           3            2           1          1               021135
INSTR GAS TEMP      153.        55.          55.         64.        64.             021135
RAW VALUE MV         30.6       468.6        573.7       415.8      914.5           021135
GAS CONCEN PPM(C)    240.5       635.2        25627.5        10.3       22.6        021135
GAS CONCEN PCT      0.0240      0.0635       2.5627      0.0010     0.0023          021135
EMISSION INDEX       9.07        48.2        3054.          1.3        2.8          021135
FUEL-AIR RATIO      0.0129                                                          021135
```

```
COMBUSTOR RIG TEST                                                                  061135
DATE                          DATA POINT             TEST CELL                      061135
 1/20/77                      061135                 1                              061135
INSTRUMENT OPERATOR                                  TEST OPERATOR                  061135
TREMBLEY                                             EHARDT                         061135
ENGINE MANUFACTURER           MODEL                  SERIAL NUMBER                  061135
LYCOMING                      ALF-502                LF04                           061135
FUEL IDENT.                   FUEL FLOW PPH          MANIFOLD FUEL TEMP FAH         061135
JET-A HC RATIO 0.160           339.                  223.9                          061135
ORIFICE AIRFLOW LB/SEC        PT3 PSIA               TT3 DEG.RANKINE                061135
  7.3                          35.1                  659.7                          061135
SIMULATED THRUST LBS          FUEL-AIR RATIO MEAS.                                  061135
 400.0                        0.0129                                                061135
SIMULATED INLET PRESSURE PO PSIA                                                    061135
14.696                                                                              061135
SIMULATED INLET TEMPERATURE TO DEG.RANKINE                                          061135
498.7                                                                               061135
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                                 061135
 33.7                                                                               061135
FILTER AREA .385 ST                                                                 061135
CLEAN CK SMOKE NUMBER 0                                                             061135
SMOKE NUMBER          VOL.-LITERS     FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH           061135
          2.3                3.0          0.50     11.310             76.0          061135
          2.3                4.0          0.52     11.360             76.0          061135
          2.3                7.0          0.50     11.360             76.0          061135
          6.7               11.0          0.50     11.340             77.0          061135
GASEOUS EMISSIONS                                                                   061135
                      FID        NDIR        NDIR        CHEMI       CHEMI          061135
                      UHC        CO          CO2         NO          NOX            061135
RANGE                 2          3           2           1           1              061135
INSTR GAS TEMP        153.       57.         57.         64.         64.            061135
RAW VALUE MV           27.6      450.1       576.1       429.0       915.2          061135
GAS CONCEN PPM(C)     216.4       598.5      25752.1       10.6         22.6        061135
GAS CONCEN PCT        0.0216     0.0599      2.5752      0.0011      0.0023         061135
EMISSION INDEX         8.15       45.3       3062.          1.3          2.8        061135
FUEL-AIR RATIO        0.0129                                                        061135
```

Reproduced from best available copy.

```
COMBUSTOR RIG TEST                                                              201145
DATE                         DATA POINT               TEST CELL                 201145
 1/20/77                     201145                   1                         201145
INSTRUMENT OPERATOR                                   TEST OPERATOR             201145
TREMBLEY                                              EHARDT                    201145
ENGINE MANUFACTURER          MODEL                    SERIAL NUMBER             201145
LYCOMING                     ALF-502                  LF04                      201145
FUEL IDENT.                  FUEL FLOW PPH            MANIFOLD FUEL TEMP FAH    201145
JET-A HC RATIO 0.160          302.                    225.6                     201145
ORIFICE AIRFLOW LB/SEC       PT3 PSIA                 TT3 DEG.RANKINE           201145
  6.3                         30.5                    683.7                     201145
SIMULATED THRUST LBS         FUEL-AIR RATIO MEAS.                               201145
 400.0                       0.0134                                             201145
SIMULATED INLET PRESSURE PO PSIA                                                201145
12.761                                                                          201145
SIMULATED INLET TEMPERATURE TO DEG.RANKINE                                      201145
518.7                                                                           201145
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                             201145
 53.3                                                                           201145
FILTER AREA .385 ST                                                             201145
CLEAN CK SMOKE NUMBER 0                                                         201145
SMOKE NUMBER         VOL.-LITERS     FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH        201145
         0.0                 3.0        0.50      11.360             77.0       201145
         0.0                 4.0        0.50      11.320             77.0       201145
         2.3                 7.0        0.48      11.320             77.0       201145
         2.3                11.0        0.50      11.320             77.0       201145
GASEOUS EMISSIONS                                                               201145
                     FID         NDIR        NDIR        CHEMI       CHEMI      201145
                     UHC          CO          CO2         NO          NOX       201145
RANGE                 2           3           2           1           1         201145
INSTR GAS TEMP       152.        56.         56.         64.         64.        201145
RAW VALUE MV          23.7       437.3       579.4       444.0       871.0      201145
GAS CONCEN PPM(C)    185.7        573.7      25918.1        11.0        21.6    201145
GAS CONCEN PCT       0.0186      0.0574      2.5918      0.0011      0.0022     201145
EMISSION INDEX        6.56        43.2       3069.          1.4         2.7     201145
FUEL-AIR RATIO       0.0130                                                     201145
```

Reproduced from
best available copy.

```
COMBUSTOR RIG TEST
DATE
 1/20/77                       DATA POINT         TEST CELL                 031135
                               031135             1                         031135
INSTRUMENT OPERATOR                                                         031135
TREMBLEY                                          TEST OPERATOR             031135
ENGINE MANUFACTURER                               EHARDT                    031135
LYCOMING                       MODEL              SERIAL NUMBER             031135
FUEL IDENT.                    ALF-502            LF04                      031135
JET-A HC RATIO 0.160           FUEL FLOW PPH      MANIFOLD FUEL TEMP FAH    031135
                                349.              225.3                     031135
ORIFICE AIRFLOW LB/SEC         PT3 PSIA           TT3 DEG.RANKINE           031135
  7.2                           35.2              666.1                     031135
SIMULATED THRUST LBS           FUEL-AIR RATIO MEAS.                         031135
 400.0                         0.0135                                       031135
SIMULATED INLET PRESSURE PO PSIA                                            031135
14.696                                                                      031135
SIMULATED INLET TEMPERATURE TO DEG.RANKINE                                  031135
518.7                                                                       031135
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                         031135
 24.6                                                                       031135
FILTER AREA .365 SI                                                         031135
CLEAN CK SMOKE NUMBER 0                                                     031135
SMOKE NUMBER        VOL.-LITERS    FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH      031135
      2.3                3.0          0.50      11.310            76.0      031135
      0.0                4.0          0.50      11.310            76.0      031135
      2.3                7.0          0.50      11.310            76.0      031135
      4.5               11.0          0.50      11.310            76.0      031135
GASEOUS EMISSIONS                                                           031135
                    FID       NDIR      NDIR       CHEMI      CHEMI         031135
                    UHC       CO         CO2       NO         NOX           031135
RANGE                2         3         2         1          2             031135
INSTR GAS TEMP      153.      58.       58.       64.        64.            031135
RAW VALUE MV         19.0     413.8     594.7     562.1      270.3          031135
GAS CONCEN PPM(C)   149.4      533.3     26826.4      13.9        26.7      031135
GAS CONCEN PCT      0.0149    0.0533    2.6826    0.0014     0.0027         031135
EMISSION INDEX       5.43      39.0     3080.        1.7        3.2         031135
FUEL-AIR RATIO      0.0134                                                  031135
                                                                            031135
```

Reproduced from
best available copy.

```
COMBUSTOR RIG TEST                                                            C71145
DATE                         DATA POINT           TEST CELL                   C71145
 1/20/77                     C71145               1                           C71145
INSTRUMENT OPERATOR                               TEST OPERATOR               C71145
TREMBLEY                                          EHARDT                      C71145
ENGINE MANUFACTURER          MODEL                SERIAL NUMBER               C71145
LYCOMING                     ALF-502              LFC4                        C71145
FUEL IDENT.                  FUEL FLOW PPH        MANIFOLD FUEL TEMP FAH      C71145
JET-A HC RATIO 0.160          348.                225.5                       C71145
ORIFICE AIRFLOW LB/SEC       PT3 PSIA             TT3 DEG.RANKINE             C71145
  7.0                         35.1                685.6                       C71145
SIMULATED THRUST LBS         FUEL-AIR RATIO MEAS.                             C71145
 400.0                       0.0137                                           C71145
SIMULATED INLET PRESSURE PO PSIA                                              C71145
14.696                                                                        C71145
SIMULATED INLET TEMPERATURE TO DEG.RANKINE                                    C71145
518.7                                                                         C71145
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                           C71145
 52.4                                                                         C71145
FILTER AREA .385 SI                                                           C71145
CLEAN CK SMOKE NUMBER 0                                                       C71145
SMOKE NUMBER          VOL.-LITERS      FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH    C71145
       2.3                    3.0          0.50      11.260            78.0   C71145
       2.3                    4.0          0.48      11.260            78.0   C71145
       4.5                    7.0          0.50      11.310            77.0   C71145
       4.5                   11.0          0.50      11.360            78.0   C71145
GASEOUS EMISSIONS                                                             C71145
                    FID        NDIR        NDIR       CHEMI       CHEMI       C71145
                    UHC         CO         CO2         NO          NOX        C71145
RANGE                2          3           2           1           1         C71145
INSTR GAS TEMP      153.       60.         60.         65.         65.        C71145
RAW VALUE MV         19.5      403.1       556.5       534.3       1007.6     C71145
GAS CONCEN PPM(C)   153.7       518.0      27072.7        13.1        24.7    C71145
GAS CONCEN PCT      0.0154     0.0518      2.7073      0.0013      0.0025     C71145
EMISSION INDEX       5.54       37.5       3082.          1.6         2.9     C71145
FUEL-AIR RATIO      0.0135                                                    C71145
```

Reproduced from best available copy.

```
COMBUSTOR RIG TEST
DATE                                                                          101145
 1/20/77                      DATA POINT             TEST CELL                101145
INSTRUMENT OPERATOR           101145                 1                        101145
TREMBLEY                                             TEST OPERATOR            101145
ENGINE MANUFACTURER                                  EHARDT                   101145
LYCOMING                      MODEL                  SERIAL NUMBER            101145
FUEL IDENT.                   ALF-502                LF04                     101145
JET-A HC RATIO 0.160          FUEL FLOW PPH          MANIFOLD FUEL TEMP FAH   101145
ORIFICE AIRFLOW LB/SEC         348.                  225.7                    101145
  7.5                         PT3 PSIA               TT3 DEG.RANKINE          101145
SIMULATED THRUST LBS           35.1                  666.5                    101145
 400.0                        FUEL-AIR RATIO MEAS.                            101145
SIMULATED INLET PRESSURE PC PSIA 0.0128                                       101145
14.696                                                                        101145
SIMULATED INLET TEMPERATURE TC DEG.RANKINE                                    101145
518.7                                                                         101145
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                           101145
 64.4                                                                         101145
FILTER AREA .385 SI                                                           101145
CLEAN CK SMOKE NUMBER 0                                                       101145
SMOKE NUMBER          VOL.-LITERS     FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH     101145
        0.0                  3.0          0.50       11.380                   101145
        0.0                  4.0          0.50       11.380          78.0     101145
        0.0                  7.0          0.50       11.380          78.0     101145
        0.0                 11.0          0.50       11.380          78.0     101145
GASEOUS EMISSIONS                                                    79.0     101145
                                                                              101145
                      FID       NDIR       NDIR      CHEMI      CHEMI         101145
                      UHC        CO         CO2       NO         NOX          101145
RANGE                  2          3          2         1          1           101145
INSTR GAS TEMP       153.       62.        62.        65.        64.          101145
RAW VALUE MV          20.8      404.7      573.6     483.2      916.3         101145
GAS CONCEN PPM(C)    164.3       526.3     25913.5       12.0       22.6      101145
GAS CONCEN PCT       0.0164     0.0526     2.5913    0.0012     0.0023        101145
EMISSION INDEX        6.18       39.8      3077.        1.5        2.8        101145
FUEL-AIR RATIO       0.0130                                                   101145
                                                                              101145
```

```
COMBUSTOR RIG TEST                                                       161145
DATE                          DATA POINT          TEST CELL              161145
 1/21/77                      161145              1                      161145
INSTRUMENT OPERATOR                               TEST OPERATOR          161145
TREMBLEY                                          EHARDT                 161145
ENGINE MANUFACTURER           MODEL               SERIAL NUMBER          161145
LYCOMING                      ALF-502             LF04                   161145
FUEL IDENT.                   FUEL FLOW PPH       MANIFOLD FUEL TEMP FAH 161145
JET-A HC RATIO 0.158           376.               226.2                  161145
ORIFICE AIRFLOW LB/SEC        PT3 PSIA            TT3 DEG.RANKINE        161145
  8.0                          37.9               686.5                  161145
SIMULATED THRUST LBS          FUEL-AIR RATIO MEAS.                       161145
 400.0                        0.0131                                     161145
SIMULATED INLET PRESSURE PO PSIA                                         161145
15.855                                                                   161145
SIMULATED INLET TEMPERATURE TO DEG.RANKINE                               161145
518.7                                                                    161145
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                      161145
 50.2                                                                    161145
FILTER AREA .385 SI                                                      161145
CLEAN CK SMOKE NUMBER 0                                                  161145
SMOKE NUMBER     VOL.-LITERS     FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH     161145
      0.0                3.0          0.50     11.460             72.0   161145
      0.0                4.0          0.50     11.410             72.0   161145
      2.3                7.0          0.50     11.410             72.0   161145
      4.5               11.0          0.48     11.380             72.0   161145
GASEOUS EMISSIONS                                                        161145
                 FID        NDIR        NDIR       CHEMI      CHEMI      161145
                 UHC        CO          CO2        NO         NOX        161145
RANGE             2          3           2          1          2         161145
INSTR GAS TEMP   153.       55.         55.        64.        64.        161145
RAW VALUE MV      18.7      403.7       557.4      531.7      259.4      161145
GAS CONCEN PPM(C) 146.5      507.9      26485.3        12.9       25.3   161145
GAS CONCEN PCT    0.0147    0.0508      2.6485     0.0013     0.0025     161145
EMISSION INDEX     5.40      37.7       3088.          1.6        3.1    161145
FUEL-AIR RATIO    0.0132                                                 161145
```

```
COMBUSTOR RIG TEST
DATE                                                                            192135
 1/21/77                  DATA POINT           TEST CELL                        192135
INSTRUMENT OPERATOR       192135               1                                192135
TREMBLEY                                       TEST OPERATOR                    192135
ENGINE MANUFACTURER       MODEL                EHARDT                           192135
LYCOMING                  ALF-502              SERIAL NUMBER                    192135
FUEL IDENT.               FUEL FLOW PPH        LF04                             192135
JET-A HC RATIO 0.158       343.                MANIFOLD FUEL TEMP FAH           192135
ORIFICE AIRFLOW LB/SEC    PT3 PSIA             226.7                            192135
  9.6                      34.9                TT3 DEG.RANKINE                  192135
SIMULATED THRUST LBS      FUEL-AIR RATIO MEAS. 689.6                            192135
 600.0                    0.0099                                                192135
SIMULATED INLET PRESSURE P0 PSIA                                                192135
12.761                                                                          192135
SIMULATED INLET TEMPERATURE T0 DEG.RANKINE                                      192135
478.7                                                                           192135
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                             192135
 24.8                                                                           192135
FILTER AREA .385 SI                                                             192135
CLEAN CK SMOKE NUMBER 0                                                         192135
SMOKE NUMBER        VOL.-LITERS       FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH       192135
         0.0                3.0            0.50      11.440              71.0   192135
         0.0                4.0            0.50      11.440              71.0   192135
         2.3                7.0            0.48      11.370              71.0   192135
         2.3               11.0            0.50      11.390              71.0   192135
GASEOUS EMISSIONS                                                               192135
                 FID          NDIR         NDIR          CHEMI       CHEMI      192135
                 UHC          CO           CO2           NO          NOX        192135
RANGE            2            3            2             1           1          192135
INSTR GAS TEMP   153.         52.          52.           63.         63.        192135
RAW VALUE MV      26.7        442.3        450.2         284.8       646.8      192135
GAS CONCEN PPM(C) 210.0        579.2        19254.3           6.9         15.7  192135
GAS CONCEN PCT   0.0210       0.0579       1.9254        0.0007      0.0016     192135
EMISSION INDEX   10.48        58.2         3040.            1.1         2.6     192135
FUEL-AIR RATIO   0.0097                                                         192135
                                                                                192135
```

```
COMBUSTOR RIG TEST
DATE                          DATA POINT        TEST CELL                 012135
 1/21/77                      012135            1                         012135
INSTRUMENT OPERATOR                             TEST OPERATOR             012135
TREMBLEY                                        EHARDT                    012135
ENGINE MANUFACTURER           MODEL             SERIAL NUMBER             012135
LYCOMING                      ALF-502           LF04                      012135
FUEL IDENT.                   FUEL FLOW PPH     MANIFOLD FUEL TEMP FAH    012135
JET-A HC RATIO 0.158           395.             222.7                     012135
ORIFICE AIRFLOW LB/SEC        PT3 PSIA          TT3 DEG.RANKINE           012135
 10.8                          40.1             691.2                     012135
SIMULATED THRUST LBS          FUEL-AIR RATIO MEAS.                        012135
 600.0                        0.0101                                      012135
SIMULATED INLET PRESSURE PO PSIA                                          012135
14.696                                                                    012135
SIMULATED INLET TEMPERATURE TO DEG.RANKINE                                012135
478.7                                                                     012135
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                       012135
 24.9                                                                     012135
FILTER AREA .365 SI                                                       012135
CLEAN CK SMOKE NUMBER 0                                                   012135
SMOKE NUMBER    VOL.-LITERS    FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH        012135
      0.0              3.0        0.50     11.440            72.0         012135
      2.3              4.0        0.48     11.360            72.0         012135
      2.3              7.0        0.50     11.390            72.0         012135
      2.3             11.0        0.50     11.390            72.0         012135
GASEOUS EMISSIONS                                                         012135
                  FID       NDIR      NDIR       CHEMI       CHEMI        012135
                  UHC        CO        CO2        NO          NOX         012135
RANGE              2          3         2          1           1          012135
INSTR GAS TEMP    153.       56.       56.        63.         63.         012135
RAW VALUE MV       23.1     413.3     466.0      331.1       732.6        012135
GAS CONCEN PPM(C) 181.7      531.2    20080.8       8.2         17.7      012135
GAS CONCEN PCT    0.0182    0.0531    2.0081     0.0008      0.0018       012135
EMISSION INDEX     8.74      51.4     3056.         1.3          2.8      012135
FUEL-AIR RATIO    0.0101                                                  012135
                                                                          012135
```

```
COMBUSTOR RIG TEST
DATE                                                                        152135
 3/ 3/77                      DATA POINT          TEST CELL                  152135
INSTRUMENT OPERATOR           152135              1                          152135
TREMBLEY                                          TEST OPERATOR              152135
ENGINE MANUFACTURER                               EHARDT                     152135
LYCOMING                      MODEL               SERIAL NUMBER              152135
FUEL IDENT.                   ALF-502             LF04                       152135
JET-A HC RATIO 0.158          FUEL FLOW PPH       MANIFOLD FUEL TEMP FAH     152135
ORIFICE AIRFLOW LB/SEC         424.               188.8                      152135
 11.6                         PT3 PSIA            TT3 DEG.RANKINE            152135
SIMULATED THRUST LBS           43.3               707.1                      152135
 600.0                        FUEL-AIR RATIO MEAS.                           152135
SIMULATED INLET PRESSURE PO PSIA 0.0101                                      152135
15.855                                                                       152135
SIMULATED INLET TEMPERATURE TO DEG.RANKINE                                   152135
478.7                                                                        152135
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                          152135
 28.1                                                                        152135
FILTER AREA .385 SI                                                          152135
CLEAN CK SMOKE NUMBER 0                                                      152135
SMOKE NUMBER      VOL.-LITERS     FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH        152135
        2.3             3.0           0.48      11.362                       152135
        4.5             4.0           0.50      11.362           77.0        152135
        2.3             7.0           0.50      11.362           77.0        152135
        8.8            11.0           0.50      11.411           77.0        152135
GASEOUS EMISSIONS                                                77.0        152135
                  FID          NDIR       NDIR        CHEMI                  152135
                  UHC          CO          CO2        NO       CHEMI         152135
RANGE              2           3           2          NO        NOX          152135
INSTR GAS TEMP    154.         45.         2          1         1            152135
RAW VALUE MV       16.3        390.9       45.        64.       64.          152135
GAS CONCEN PPM(C)  142.8        478.1      465.2      351.0     781.6        152135
GAS CONCEN PCT    0.0143       0.0478       20073.1       8.3       18.6     152135
EMISSION INDEX     6.90         46.5       2.0073     0.0008    0.0019       152135
FUEL-AIR RATIO    0.0100                   3069.          1.3        3.0     152135
                                                                             152135
```

```
COMBUSTOR RIG TEST                                                   C22135
DATE                         CATA PCINT              TEST CELL       C22135
 1/21/77                     C22135                  1               C22135
INSTRUMENT OPERATCR                                  TEST CPERATCR   C22135
TREMBLEY                                             EHARCT          C22135
ENGINE MANUFACTURER          MCDEL                   SERIAL NUMBER   C22135
LYCOMING                     ALF-5C2                 LF04            022135
FUEL IDENT.                  FUEL FLCW PPH           MANIFCLC FUEL TEMP FAH  C22135
JET-A HC RATIO C.158          405.                   224.8           C22135
ORIFICE AIRFLOW LB/SEC       PT3 PSIA                TT3 CEG.RANKINE 022135
 10.8                         40.1                   717.8           022135
SIMULATED THRUST LBS         FUEL-AIR RATIC MEAS.                    022135
 600.0                       C.0104                                  022135
SIMULATED INLET PRESSURE FC PSIA                                     022135
14.696                                                               022135
SIMULATED INLET TEMPERATURE TC DEG.RANKINE                           C22135
498.7                                                                022135
SPECIFIC HUMIDITY GRAINS/LB CRY AIR                                  C22135
 24.6                                                                022135
FILTER AREA .385 SI                                                  C22135
CLEAN CK SMOKE NUMBER 0                                              C22135
SMOKE NUMBER    VCL.-LITERS    FLCW-CFM PRESS.-PSIA  TEMP. DEG.FAH   C22135
      0.0            3.0          C.50      11.380            74.C   022135
      0.0            4.C          C.50      11.380            74.C   022135
      2.3            7.C          C.50      11.430            75.C   C22135
      2.3           11.C          C.50      11.38C            75.C   022135
GASEOUS EMISSICNS                                                    022135
                  FIC       NDIR      NDIR      CHEMI     CHEMI      C22135
                  UHC       CO        CC2       NO        NOX        C22135
RANGE             2         3         2         1         1          022135
INSTR GAS TEMP    153.      54.       54.       64.       64.        022135
RAW VALUE MV       18.8     405.7     481.0     406.C     810.4      C22135
GAS CONCEN PPM(C) 147.2      517.3    2C8C6.1      10.C      19.6    022135
GAS CONCEN PCT    C.C147    C.0517    2.C806    0.CC1C    0.CC2C     C22135
EMISSION INDEX     6.85      48.5     3C66.        1.5       3.0     C22135
FUEL-AIR RATIC    C.C1C4                                             022135
```

```
COMBUSTOR RIG TEST                                                              062145
DATE                          DATA POINT            TEST CELL                   062145
 1/21/77                      062145                1                           062145
INSTRUMENT OPERATOR                                 TEST OPERATOR               062145
TREMBLEY                                            EHARDT                      062145
ENGINE MANUFACTURER           MODEL                 SERIAL NUMBER               062145
LYCOMING                      ALF-502               LF04                        062145
FUEL IDENT.                   FUEL FLOW PPH         MANIFOLD FUEL TEMP FAH      062145
JET-A HC RATIO 0.158           405.                 224.7                       062145
ORIFICE AIRFLOW LB/SEC        PT3 PSIA              TT3 DEG.RANKINE             062145
 10.8                          40.2                 717.9                       062145
SIMULATED THRUST LBS          FUEL-AIR RATIO MEAS.                              062145
 600.0                        0.0105                                            062145
SIMULATED INLET PRESSURE PO PSIA                                                062145
14.696                                                                          062145
SIMULATED INLET TEMPERATURE TO DEG.RANKINE                                      062145
498.7                                                                           062145
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                             062145
 33.5                                                                           062145
FILTER AREA .385 SI                                                             062145
CLEAN CK SMOKE NUMBER 0                                                         062145
SMOKE NUMBER      VOL.-LITERS     FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH           062145
         2.3              3.0         0.50    11.430               76.0         062145
         2.3              4.0         0.48    11.380               76.0         062145
         2.3              7.0         0.50    11.380               76.0         062145
         2.3             11.0         0.50    11.410               76.0         062145
GASEOUS EMISSIONS                                                               062145
                    FID       NDIR       NDIR      CHEMI      CHEMI             062145
                    UHC        CO        CO2        NO         NOX              062145
RANGE                2         3          2         1          1                062145
INSTR GAS TEMP      153.      53.        53.       63.        63.               062145
RAW VALUE MV         19.0     406.2      483.4     402.2      793.6             062145
GAS CONCEN PPM(C)   149.0      518.2     20921.9        9.9        19.2         062145
GAS CONCEN PCT      0.0149    0.0518     2.0922    0.0010     0.0019            062145
EMISSION INDEX       6.90      48.3      3066.        1.5        2.9            062145
FUEL-AIR RATIO      0.0105                                                      062145
```

```
COMBUSTOR RIG TEST
DATE                                                                                041135
 1/21/77                           DATA POINT              TEST CELL               041135
                                   041135                  1                       041135
INSTRUMENT OPERATOR                                        TEST OPERATOR           041135
TREMBLEY                                                   EHARDT                  041135
ENGINE MANUFACTURER                MODEL                   SERIAL NUMBER           041135
LYCOMING                           ALF-502                 LF04                    041135
FUEL IDENT.                        FUEL FLOW PPH           MANIFOLD FUEL TEMP FAH  041135
JET-A HC RATIO 0.158                360.                   227.7                   041135
ORIFICE AIRFLOW LB/SEC             PT3 PSIA                TT3 DEG.RANKINE         041135
  7.0                               35.0                   720.3                   041135
SIMULATED THRUST LBS               FUEL-AIR RATIO MEAS.                            041135
 400.0                             0.0143                                          041135
SIMULATED INLET PRESSURE PO PSIA                                                   041135
14.696                                                                             041135
SIMULATED INLET TEMPERATURE TO DEG.RANKINE                                         041135
544.7                                                                              041135
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                                041135
 24.7                                                                              041135
FILTER AREA .385 SI                                                                041135
CLEAN CK SMOKE NUMBER 0                                                            041135
SMOKE NUMBER        VOL.-LITERS    FLOW-CFM PRESS.-PSIA   TEMP. DEG.FAH            041135
        2.3                 3.0        0.50    11.430              74.0            041135
        2.3                 4.0        0.50    11.430              74.0            041135
        2.3                 7.0        0.52    11.390              75.0            041135
        2.3                11.0        0.50    11.390              75.0            041135
GASEOUS EMISSIONS                                                                  041135
                     FID       NDIR       NDIR      CHEMI      CHEMI               041135
                     UHC       CO         CO2       NO         NOX                 041135
RANGE                2         2          2         1          2                   041135
INSTR GAS TEMP      153.       55.        55.       63.        63.                 041135
RAW VALUE MV         12.1     902.1      645.6     772.5      313.1                041135
GAS CONCEN PPM(C)    93.8      450.1    29055.3      18.7        30.0              041135
GAS CONCEN PCT      0.0094    0.0450     2.9055    0.0019      0.0030              041135
EMISSION INDEX       3.17      30.6      3106.        2.1         3.4              041135
FUEL-AIR RATIO      0.0144                                                         041135
                                                                                   041135
```

```
COMBUSTOR RIG TEST                                                              C81145
DATE                              DATA POINT              TEST CELL             C81145
 1/21/77                          C81145                  1                     C81145
INSTRUMENT OPERATOR                                       TEST OPERATOR         C81145
TREMBLEY                                                  EHARCT                C81145
ENGINE MANUFACTURER               MODEL                   SERIAL NUMBER         C81145
LYCOMING                          ALF-502                 LF04                  C81145
FUEL IDENT.                       FUEL FLOW PPH           MANIFOLD FUEL TEMP FAH C81145
JET-A HC RATIO 0.158               360.                   225.2                 C81145
ORIFICE AIRFLOW LB/SEC            PT3 PSIA                TT3 DEG.RANKINE       C81145
  6.9                              35.0                   719.0                 081145
SIMULATED THRUST LBS              FUEL-AIR RATIO MEAS.                          C81145
 400.0                            0.0145                                        C81145
SIMULATED INLET PRESSURE P0 PSIA                                                C81145
14.696                                                                          C81145
SIMULATED INLET TEMPERATURE T0 DEG.RANKINE                                      C81145
544.7                                                                           C81145
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                             C81145
 51.4                                                                           C81145
FILTER AREA .385 SI                                                             C81145
CLEAN CK SMOKE NUMBER 0                                                         C81145
SMOKE NUMBER        VOL.-LITERS    FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH          C81145
        0.0                 3.0        0.50     11.430            73.0          C81145
        0.0                 4.0        0.50     11.390            73.0          C81145
        2.3                 7.0        0.50     11.430            73.0          C81145
        2.3                11.0        0.50     11.390            74.0          C81145
GASEOUS EMISSIONS                                                               C81145
                 FID        NDIR       NDIR       CHEMI      CHEMI              C81145
                 UHC         CO         CO2        NO         NOX               C81145
RANGE             1          2          2          1          2                 C81145
INSTR GAS TEMP   153.       54.        54.        64.        63.                C81145
RAW VALUE MV     122.0      877.3      646.2      721.2      293.7              C81145
GAS CONCEN PPM(C)  95.6      435.2     29088.8        17.4       28.1           C81145
GAS CONCEN PCT   0.0096     0.0435     2.9089     0.0017     0.0028             C81145
EMISSION INDEX    3.23       29.6      3107.         1.9        3.1             C81145
FUEL-AIR RATIO   0.0144                                                         C81145
```

```
COMBUSTOR RIG TEST                                                      111145
DATE                          DATA POINT          TEST CELL             111145
 1/21/77                      111145              1                     111145
INSTRUMENT OPERATOR                               TEST OPERATOR         111145
TREMBLEY                                          EHARDT                111145
ENGINE MANUFACTURER           MODEL               SERIAL NUMBER         111145
LYCOMING                      ALF-502             LF04                  111145
FUEL IDENT.                   FUEL FLOW PPH       MANIFOLD FUEL TEMP FAH 111145
JET-A HC RATIO 0.158           360.               224.6                 111145
ORIFICE AIRFLOW LB/SEC        PT3 PSIA            TT3 DEG.RANKINE       111145
  6.8                          35.1               718.8                 111145
SIMULATED THRUST LBS          FUEL-AIR RATIO MEAS.                      111145
 400.0                        0.0147                                    111145
SIMULATED INLET PRESSURE PC PSIA                                        111145
14.696                                                                  111145
SIMULATED INLET TEMPERATURE TC DEG.RANKINE                              111145
544.7                                                                   111145
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                     111145
101.7                                                                   111145
FILTER AREA .385 SI                                                     111145
CLEAN CK SMOKE NUMBER 0                                                 111145
SMOKE NUMBER     VOL.-LITERS     FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH    111145
     0.0               3.0          0.50    11.430             73.0     111145
     2.3               4.0          0.50    11.430             73.0     111145
     2.3               7.0          0.50    11.390             73.0     111145
     2.3              11.0          0.50    11.430             73.0     111145
GASEOUS EMISSIONS                                                       111145
                 FID         NDIR        NDIR        CHEMI      CHEMI   111145
                 UHC          CO          CO2         NO         NOX    111145
RANGE             2           2           2           1          2      111145
INSTR GAS TEMP   153.        52.         52.         63.        63.     111145
RAW VALUE MV      13.6       887.0       649.0       646.0      258.2   111145
GAS CONCEN PPM(C) 106.3       441.0      29229.3        15.6       24.7 111145
GAS CONCEN PCT   0.0106      0.0441      2.9229      0.0016     0.0025  111145
EMISSION INDEX    3.57        29.8       3106.          1.7        2.7  111145
FUEL-AIR RATIO   0.0145                                                 111145
```

```
COMBUSTOR RIG TEST                                                                   131145
DATE                            DATA POINT             TEST CELL                     131145
 1/21/77                        131145                 1                             131145
INSTRUMENT OPERATOR                                    TEST OPERATOR                 131145
TREMBLEY                                               EHARDT                        131145
ENGINE MANUFACTURER             MODEL                  SERIAL NUMBER                 131145
LYCOMING                        ALF-502                LF04                          131145
FUEL IDENT.                     FUEL FLOW PPH          MANIFOLD FUEL TEMP FAH        131145
JET-A HC RATIO 0.158             360.                  225.0                         131145
ORIFICE AIRFLOW LB/SEC          PT3 PSIA               TT3 DEG.RANKINE               131145
  6.7                            35.0                  723.4                         131145
SIMULATED THRUST LBS            FUEL-AIR RATIO MEAS.                                 131145
 400.0                          0.0150                                               131145
SIMULATED INLET PRESSURE PO PSIA                                                     131145
14.696                                                                               131145
SIMULATED INLET TEMPERATURE TO DEG.RANKINE                                           131145
544.7                                                                                131145
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                                  131145
166.8                                                                                131145
FILTER AREA .385 SI                                                                  131145
CLEAN CK SMOKE NUMBER 0                                                              131145
SMOKE NUMBER         VOL.-LITERS      FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH            131145
       0.0                  3.0          0.50     11.390              71.0           131145
       0.0                  4.0          0.50     11.390              71.0           131145
       2.3                  7.0          0.48     11.340              72.0           131145
       2.3                 11.0          0.48     11.340              72.0           131145
GASEOUS EMISSIONS                                                                    131145
                     FID         NDIR         NDIR         CHEMI        CHEMI        131145
                     UHC          CO          CO2           NO           NOX         131145
RANGE                 2           2            2            1            1           131145
INSTR GAS TEMP       153.        55.          55.          63.          63.          131145
RAW VALUE MV          18.1       931.2        653.4        544.3        860.1        131145
GAS CONCEN PPM(C)     142.0       465.3        29386.9         13.5         21.1     131145
GAS CONCEN PCT       0.0142      0.0465       2.9387       0.0014       0.0021       131145
EMISSION INDEX        4.73        31.2        3100.           1.5          2.3       131145
FUEL-AIR RATIO       0.0146                                                          131145
```

```
COMBUSTOR RIG TEST                                                               202145
DATE                          DATA POINT          TEST CELL                      202145
 1/21/77                      202145              1                              202145
INSTRUMENT OPERATOR                                                              202145
TREMBLEY                                          TEST OPERATOR                  202145
ENGINE MANUFACTURER                               EHARDT                         202145
LYCOMING                      MODEL               SERIAL NUMBER                  202145
FUEL IDENT.                   ALF-502             LFC4                           202145
JET-A HC RATIO 0.158          FUEL FLOW PPH       MANIFOLD FUEL TEMP FAH         202145
ORIFICE AIRFLOW LB/SEC         362.               226.4                          202145
  9.1                         PT3 PSIA            TT3 DEG.RANKINE                202145
SIMULATED THRUST LBS           34.9               745.8                          202145
 600.0                        FUEL-AIR RATIO MEAS.                               202145
SIMULATED INLET PRESSURE PO PSIA                                                 202145
12.761                                                                           202145
SIMULATED INLET TEMPERATURE TO DEG.RANKINE                                       202145
518.7                                                                            202145
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                              202145
 48.7                                                                            202145
FILTER AREA .385 SI                                                              202145
CLEAN CK SMOKE NUMBER 0                                                          202145
SMOKE NUMBER      VOL.-LITERS    FLOW-CFM PRESS.-PSIA   TEMP. DEG.FAH            202145
          2.3             3.0         0.50     11.440            72.0            202145
          0.0             4.0         0.50     11.440            72.0            202145
          2.3             7.0         0.52     11.440            72.0            202145
          2.3            11.0         0.52     11.440            72.0            202145
GASEOUS EMISSIONS                                                                202145
                  FID       NDIR      NDIR       CHEMI     CHEMI                 202145
                  UHC        CO        CO2        NO        NOX                  202145
RANGE              2         3          2         1         1                    202145
INSTR GAS TEMP    153.      52.        52.       63.       63.                   202145
RAW VALUE MV       19.7     427.8      504.0     417.3     787.3                 202145
GAS CONCEN PPM(C) 154.6      556.3     21908.0      10.5      19.3               202145
GAS CONCEN PCT    0.0155    0.0556     2.1908    0.0010    0.0019                202145
EMISSION INDEX     6.84      49.5      3065.        1.5       2.8                202145
FUEL-AIR RATIO    0.0110                                                         202145
                                                                                 202145
```

```
COMBUSTOR RIG TEST                                                           032135
DATE                          DATA POINT             TEST CELL               032135
 1/24/77                      032135                 1                       032135
INSTRUMENT OPERATOR                                  TEST OPERATOR           032135
TREMBLEY                                             EHARDT                  032135
ENGINE MANUFACTURER           MODEL                  SERIAL NUMBER           032135
LYCOMING                      ALF-502                LF04                    032135
FUEL IDENT.                   FUEL FLOW PPH          MANIFOLD FUEL TEMP FAH  032135
JET-A HC RATIO 0.158           418.                  226.4                   032135
ORIFICE AIRFLOW LB/SEC        PT3 PSIA               TT3 DEG.RANKINE         032135
 10.5                          40.3                  747.1                   032135
SIMULATED THRUST LBS          FUEL-AIR RATIO MEAS.                           032135
 600.0                         0.0110                                        032135
SIMULATED INLET PRESSURE PO PSIA                                             032135
14.696                                                                       032135
SIMULATED INLET TEMPERATURE TO DEG.RANKINE                                   032135
518.7                                                                        032135
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                          032135
 24.5                                                                        032135
FILTER AREA .385 SI                                                          032135
CLEAN CK SMOKE NUMBER 0                                                      032135
SMOKE NUMBER       VOL.-LITERS     FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH       032135
        0.0                3.0         0.50     11.610             72.0      032135
        2.3                4.0         0.50     11.610             72.0      032135
        0.0                7.0         0.50     11.610             71.0      032135
        0.0               11.0         0.50     11.560             71.0      032135
GASEOUS EMISSIONS                                                            032135
                   FID        NDIR        NDIR       CHEMI      CHEMI        032135
                   UHC         CO          CO2        NO         NOX         032135
RANGE              2           3           2          1          1           032135
INSTR GAS TEMP   153.        55.         55.        64.        64.           032135
RAW VALUE MV       15.8      413.0       501.6      491.3      511.4         032135
GAS CONCEN PPM(C)  124.4       528.0     22057.3       11.9       22.1       032135
GAS CONCEN PCT   0.0124      0.0528      2.2057     0.0012     0.0022        032135
EMISSION INDEX     5.48        46.8      3073.         1.7        3.2        032135
FUEL-AIR RATIO   0.0110                                                      032135
```

```
COMBUSTOR RIG TEST                                                          C72145
DATE                            DATA POINT          TEST CELL               C72145
 1/24/77                        C72145              1                       C72145
INSTRUMENT OPERATOR                                 TEST OPERATOR           072145
TREMBLEY                                            EHARDT                  072145
ENGINE MANUFACTURER             MODEL               SERIAL NUMBER           C72145
LYCOMING                        ALF-502             LF04                    072145
FUEL IDENT.                     FUEL FLOW PPH       MANIFOLD FUEL TEMP FAH  C72145
JET-A HC RATIO 0.158             417.               225.8                   072145
ORIFICE AIRFLOW LB/SEC          PT3 PSIA            TT3 DEG.RANKINE         C72145
 10.4                            40.2               746.5                   072145
SIMULATED THRUST LBS            FUEL-AIR RATIO MEAS.                        072145
 600.0                          0.0112                                      072145
SIMULATED INLET PRESSURE PO PSIA                                            C72145
14.696                                                                      072145
SIMULATED INLET TEMPERATURE TO DEG.RANKINE                                  C72145
518.7                                                                       C72145
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                         072145
 51.4                                                                       C72145
FILTER AREA .385 SI                                                         C72145
CLEAN CK SMOKE NUMBER 0                                                     C72145
SMOKE NUMBER        VOL.-LITERS     FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH     C72145
       2.3                 3.0          0.50    11.590             71.0     072145
       2.3                 4.0          0.52    11.540             71.0     C72145
       0.0                 7.0          0.52    11.590             72.0     C72145
       0.0                11.0          0.50    11.540             73.0     C72145
GASEOUS EMISSIONS                                                           C72145
                    FID        NDIR        NDIR        CHEMI     CHEMI      C72145
                    UHC         CO          CO2         NO        NOX       072145
RANGE                2          3           2           1         1         C72145
INSTR GAS TEMP      153.       54.         54.         64.       63.        C72145
RAW VALUE MV         16.0      406.7       504.1       501.4     849.0      072145
GAS CONCEN PPM(C)   126.0       516.7      22182.9        12.2      20.6    C72145
GAS CONCEN PCT      0.0126     0.0517      2.2183      0.0012    0.0021     072145
EMISSION INDEX       5.52       45.6       3075.          1.8       3.0     C72145
FUEL-AIR RATIO      0.0111                                                  C72145
```

```
COMBUSTOR RIG TEST
DATE                            DATA POINT          TEST CELL                     102145
 1/24/77                        102145              1                             102145
INSTRUMENT OPERATOR                                                               102145
TREMBLEY                                            TEST OPERATOR                 102145
ENGINE MANUFACTURER                                 EHARDT                        102145
LYCOMING                        MODEL               SERIAL NUMBER                 102145
FUEL IDENT.                     ALF-502             LF04                          102145
JET-A HC RATIO 0.158            FUEL FLOW PPH       MANIFOLD FUEL TEMP FAH        102145
ORIFICE AIRFLOW LB/SEC           416.               225.3                         102145
 10.4                           PT3 PSIA            TT3 DEG.RANKINE               102145
SIMULATED THRUST LBS             40.2               746.9                         102145
 600.0                          FUEL-AIR RATIO MEAS.                              102145
                                0.0111                                            102145
SIMULATED INLET PRESSURE PO PSIA                                                  102145
14.696                                                                            102145
SIMULATED INLET TEMPERATURE TO DEG.RANKINE                                        102145
518.7                                                                             102145
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                               102145
 67.0                                                                             102145
FILTER AREA .385 SI                                                               102145
CLEAN CK SMOKE NUMBER 0                                                           102145
SMOKE NUMBER       VOL.-LITERS       FLOW-CFM PRESS.-PSIA   TEMP. DEG.FAH         102145
       2.3                3.0           0.50     11.560             72.0          102145
       0.0                4.0           0.50     11.540             72.0          102145
       0.0                7.0           0.49     11.540             72.0          102145
       0.0               11.0           0.50     11.540             73.0          102145
GASEOUS EMISSIONS                                                                 102145
                   FID         NDIR        NDIR        CHEMI        CHEMI         102145
                   UHC         CO          CO2         NO           NOX           102145
RANGE               2           3           2           1            1            102145
INSTR GAS TEMP     153.        52.         52.         64.          64.           102145
RAW VALUE MV        18.8       410.3       502.4       443.5        819.7         102145
GAS CONCEN PPM(C)  148.4       523.1     22098.7        10.8         19.9         102145
GAS CONCEN PCT     0.0148      0.0523      2.2099      0.0011       0.0020        102145
EMISSION INDEX      6.52       46.3       3071.          1.6          2.9         102145
FUEL-AIR RATIO     0.0111                                                         102145
                                                                                  102145
```

```
COMBUSTOR RIG TEST
DATE                                                                   162145
 3/ 3/77                      DATA POINT           TEST CELL           162145
INSTRUMENT OPERATOR           162145               1                   162145
TREMBLEY                                           TEST OPERATOR       162145
ENGINE MANUFACTURER                                EHARDT              162145
LYCOMING                      MODEL                SERIAL NUMBER       162145
FUEL IDENT.                   ALF-502              LF04                162145
JET-A HC RATIO 0.158          FUEL FLOW PPH        MANIFOLD FUEL TEMP FAH 162145
ORIFICE AIRFLOW LB/SEC         449.                225.6               162145
 11.1                         PT3 PSIA             TT3 DEG.RANKINE     162145
SIMULATED THRUST LBS           43.5                745.4               162145
 600.0                        FUEL-AIR RATIO MEAS.                     162145
SIMULATED INLET PRESSURE PO PSIA  0.0112                               162145
15.855                                                                 162145
SIMULATED INLET TEMPERATURE TC DEG.RANKINE                             162145
518.7                                                                  162145
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                    162145
 48.6                                                                  162145
FILTER AREA .385 SI                                                    162145
CLEAN CK SMOKE NUMBER 0                                                162145
SMOKE NUMBER        VOL.-LITERS      FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH 162145
      0.0                  3.0          0.48      11.411                 162145
      4.5                  4.0          0.50      11.411            75.0 162145
      0.0                  7.0          0.48      11.411            75.0 162145
      4.5                 11.0          0.48      11.411            75.0 162145
GASEOUS EMISSIONS                                                   75.0 162145
                  FID        NDIR        NDIR        CHEMI       CHEMI   162145
                  UHC        CO          CO2         NO          NOX     162145
RANGE              2          2           2           1           1      162145
INSTR GAS TEMP   153.        56.         56.         64.         64.     162145
RAW VALUE MV      13.3       857.5       516.9       441.7       882.0   162145
GAS CONCEN PPM(C) 115.8      451.6       22583.3       11.1        21.9  162145
GAS CONCEN PCT   0.0116      0.0452      2.2583      0.0011      0.0022  162145
EMISSION INDEX    5.00       39.3        3087.         1.6         3.1   162145
FUEL-AIR RATIO   0.0112                                                  162145
                                                                         162145
```

```
COMBUSTOR RIG TEST                                                                 211135
DATE                           DATA POINT          TEST CELL                       211135
 1/25/77                       211135              1                               211135
INSTRUMENT OPERATOR                                TEST OPERATOR                   211135
TREMBLEY                                           EHARDT                          211135
ENGINE MANUFACTURER            MODEL               SERIAL NUMBER                   211135
LYCOMING                       ALF-502             LF04                            211135
FUEL IDENT.                    FUEL FLOW PPH       MANIFOLD FUEL TEMP FAH          211135
JET-A HC RATIO 0.158            322.               224.0                           211135
ORIFICE AIRFLOW LB/SEC         PT3 PSIA            TT3 DEG.RANKINE                 211135
  6.1                           30.5               746.4                           211135
SIMULATED THRUST LBS           FUEL-AIR RATIO MEAS.                                211135
 400.0                         0.0147                                              211135
SIMULATED INLET PRESSURE PC PSIA                                                   211135
12.761                                                                             211135
SIMULATED INLET TEMPERATURE TC DEG.RANKINE                                         211135
564.7                                                                              211135
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                                211135
 25.9                                                                              211135
FILTER AREA .385 SI                                                                211135
CLEAN CK SMOKE NUMBER 0                                                            211135
SMOKE NUMBER       VOL.-LITERS     FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH             211135
      0.0                 3.0         0.50    11.300               74.0            211135
      0.0                 4.0         0.50    11.250               74.0            211135
      0.0                 7.0         0.51    11.300               75.0            211135
      2.3                11.0         0.50    11.250               75.0            211135
GASEOUS EMISSIONS                                                                  211135
                   FID         NDIR        NDIR        CHEMI       CHEMI           211135
                   UHC          CO          CO2         NO          NOX            211135
RANGE               1           2           2           2           2              211135
INSTR GAS TEMP     153.        58.         58.         64.         64.             211135
RAW VALUE MV       103.8       887.1       653.5       212.6       313.5           211135
GAS CONCEN PPM(C)    82.7       446.4      30103.1        20.6        30.6         211135
GAS CONCEN PCT     0.0083      0.0446      3.0103      0.0021      0.0031          211135
EMISSION INDEX      2.70        29.3       3109.         2.2         3.3           211135
FUEL-AIR RATIO     0.0149                                                          211135
```

```
COMBUSTOR RIG TEST                                                       221145
DATE                         CATA FOINT            TEST CELL             221145
 1/25/77                     221145                I                     221145
INSTRUMENT OPERATOR                                TEST OPERATOR         221145
TREMBLFY                                           EFARCT                221145
ENGINE MANUFACTURER          MCDEL                 SERIAL NUMBER         221145
LYCOMING                     ALF-5C2               LF04                  221145
FUEL IDENT.                  FUEL FLCW PPH         MANIFCLD FUEL TEMP FAH 221145
JET-A HC RATIO C.158          322.                 224.2                 221145
ORIFICE AIRFLOW LB/SEC       PT3 PSIA              TT3 DEG.RANKINE       221145
  5.8                         30.5                 746.9                 221145
SIMULATED THRUST LBS         FUEL-AIR RATIC MEAS.                        221145
 400.0                       C.0154                                      221145
SIMULATED INLET PRESSURE PC PSIA                                         221145
12.761                                                                   221145
SIMULATED INLET TEMPERATURE TC DEG.RANKINE                               221145
564.7                                                                    221145
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                      221145
176.3                                                                    221145
FILTER AREA .385 SI                                                      221145
CLEAN CK SMOKE NUMBER C                                                  221145
SMOKE NUMBER        VCL.-LITERS     FLCW-CFM PRESS.-PSIA  TEMP. DEG.FAH  221145
      0.0                   3.0          C.50     11.230           76.0  221145
      0.0                   4.C          C.50     11.24C           76.C  221145
      0.0                   7.0          C.50     11.24C           76.0  221145
      2.3                  11.0          C.48     11.23C           78.0  221145
GASEOUS EMISSICNS                                                        221145
                  FIC         NDIR        NCIR        CHEMI       CHEMI  221145
                  UHC         CO          CO2         NO          NOX    221145
RANGE              2           2           2          1           1      221145
INSTR GAS TEMP    153.        57.         57.         64.         64.    221145
RAW VALUE MV       13.2       879.4       664.2       599.7       878.C  221145
GAS CONCEN PPM(C) 104.4        441.7       30678.3        14.6      21.4  221145
GAS CONCEN PCT    C.C1C4      C.0442      3.C678      0.CC15      0.CC21 221145
EMISSION INDEX     3.34        28.5        31C9.          1.5        2.3  221145
FUEL-AIR RATIC    C.C152                                                 221145
```

```
COMBUSTOR RIG TEST                                                                            051135
DATE                              DATA POINT          TEST CELL                               051135
  1/25/77                         051135              1                                       051135
INSTRUMENT OPERATOR                                   TEST OPERATOR                           051135
TREMBLEY                                              EHARDT                                  051135
ENGINE MANUFACTURER               MODEL               SERIAL NUMBER                           051135
LYCOMING                          ALF-502             LFC4                                    051135
FUEL IDENT.                       FUEL FLOW PPH       MANIFOLD FUEL TEMP FAH                  051135
JET-A HC RATIO 0.158               370.               222.5                                   051135
ORIFICE AIRFLOW LB/SEC            PT3 PSIA            TT3 DEG.RANKINE                         051135
   7.1                             35.1               747.8                                   051135
SIMULATED THRUST LBS              FUEL-AIR RATIO MEAS.                                        051135
 400.0                            0.0145                                                      051135
SIMULATED INLET PRESSURE PO PSIA                                                              051135
14.696                                                                                        051135
SIMULATED INLET TEMPERATURE TO DEG.RANKINE                                                    051135
564.7                                                                                         051135
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                                           051135
 25.8                                                                                         051135
FILTER AREA .385 SI                                                                           051135
CLEAN CK SMOKE NUMBER 0                                                                       051135
SMOKE NUMBER          VOL.-LITERS      FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH                    051135
         0.0                 3.0             0.50     11.290              76.0                051135
         0.0                 4.0             0.49     11.240              76.0                051135
         0.0                 7.0             0.50     11.240              75.0                051135
         2.3                11.0             0.52     11.290              76.0                051135
GASEOUS EMISSIONS                                                                             051135
                       FID         NDIR        NDIR        CHEMI       CHEMI                  051135
                       UHC          CO          CO2         NO          NOX                   051135
RANGE                   1           2           2           2           2                     051135
INSTR GAS TEMP         153.        61.         61.         64.         65.                    051135
RAW VALUE MV            55.8       648.6       647.3       223.3       336.4                  051135
GAS CONCEN PPM(C)        76.4       423.7     29855.3        21.5        32.6                 051135
GAS CONCEN PCT         0.0076      0.0424      2.9855      0.0022      0.0033                 051135
EMISSION INDEX          2.52        28.1       3112.          2.3         3.5                 051135
FUEL-AIR RATIO         0.0148                                                                 051135
```

```
COMBUSTOR RIG TEST                                                            091145
DATE                        DATA POINT           TEST CELL                    091145
 1/25/77                    091145               1                            091145
INSTRUMENT OPERATOR                              TEST OPERATOR                091145
TREMBLEY                                         EHARDT                       091145
ENGINE MANUFACTURER         MODEL                SERIAL NUMBER                091145
LYCOMING                    ALF-502              LF04                         091145
FUEL IDENT.                 FUEL FLOW PPH        MANIFOLD FUEL TEMP FAH       091145
JET-A HC RATIO 0.158         371.                222.5                        091145
ORIFICE AIRFLOW LB/SEC      PT3 PSIA             TT3 DEG.RANKINE              091145
  7.1                        35.1                747.0                        091145
SIMULATED THRUST LBS        FUEL-AIR RATIO MEAS.                              091145
 400.0                      0.0145                                            091145
SIMULATED INLET PRESSURE PO PSIA                                              091145
14.696                                                                        091145
SIMULATED INLET TEMPERATURE TO DEG.RANKINE                                    091145
564.7                                                                         091145
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                           091145
 50.1                                                                         091145
FILTER AREA .365 SI                                                           091145
CLEAN CK SMOKE NUMBER 0                                                       091145
SMOKE NUMBER        VOL.-LITERS      FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH      091145
          0.0                3.0         0.50     11.290            74.0      091145
          0.0                4.0         0.52     11.290            74.0      091145
          0.0                7.0         0.50     11.290            73.0      091145
          2.3               11.0         0.51     11.290            75.0      091145
GASEOUS EMISSIONS                                                             091145
                    FID         NDIR        NDIR         CHEMI      CHEMI     091145
                    UHC          CO          CO2          NO         NOX      091145
RANGE                1           2            2           2          2        091145
INSTR GAS TEMP      153.        57.          57.         64.        64.       091145
RAW VALUE MV         55.9       837.7        653.3       209.5      317.0     091145
GAS CONCEN PPM(C)     76.5       417.4       30174.8        20.2        30.7  091145
GAS CONCEN PCT      0.0076      0.0417       3.0175      0.0020     0.0031    091145
EMISSION INDEX       2.49        27.4        3113.          2.2        3.3    091145
FUEL-AIR RATIO      0.0149                                                    091145
```

```
COMBUSTOR RIG TEST                                                                121145
DATE                              DATA POINT             TEST CELL                121145
 1/25/77                          121145                 1                        121145
INSTRUMENT OPERATOR                                      TEST OPERATOR            121145
TREMBLEY                                                 EHARDT                   121145
ENGINE MANUFACTURER               MODEL                  SERIAL NUMBER            121145
LYCOMING                          ALF-502                LF04                     121145
FUEL IDENT.                       FUEL FLOW PPH          MANIFOLD FUEL TEMP FAH   121145
JET-A HC RATIO 0.158               370.                  223.3                    121145
ORIFICE AIRFLOW LB/SEC            PT3 PSIA               TT3 DEG.RANKINE          121145
  6.9                              35.1                  747.7                    121145
SIMULATED THRUST LBS              FUEL-AIR RATIO MEAS.                            121145
 400.0                            0.0148                                          121145
SIMULATED INLET PRESSURE P0 PSIA                                                  121145
14.696                                                                            121145
SIMULATED INLET TEMPERATURE T0 DEG.RANKINE                                        121145
564.7                                                                             121145
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                               121145
105.2                                                                             121145
FILTER AREA .385 SI                                                               121145
CLEAN CK SMOKE NUMBER 0                                                           121145
SMOKE NUMBER        VOL.-LITERS     FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH           121145
        0.0                 3.0         0.50     11.270           75.0            121145
        0.0                 4.0         0.49     11.250           75.0            121145
        0.0                 7.0         0.50     11.290           76.0            121145
        2.3                11.0         0.50     11.250           75.0            121145
GASEOUS EMISSIONS                                                                 121145
                 FID        NDIR        NDIR        CHEMI       CHEMI             121145
                 UHC         CO          CO2         NO          NOX              121145
RANGE             1          2           2           2           2                121145
INSTR GAS TEMP   153.        56.         56.         64.         64.              121145
RAW VALUE MV     108.7       836.8       657.8       180.6       276.7            121145
GAS CONCEN PPM(C)  86.7       416.8      30414.7       17.4        26.8           121145
GAS CONCEN PCT   0.0087      0.0417      3.0415      0.0017      0.0027           121145
EMISSION INDEX     2.80        27.2      3113.          1.9         2.9           121145
FUEL-AIR RATIO   0.0151                                                           121145
```

```
COMBUSTOR RIG TEST                                                                    141145
DATE                          DATA POINT            TEST CELL                         141145
 1/26/77                      141145                1                                 141145
INSTRUMENT OPERATOR                                 TEST OPERATOR                     141145
TREMBLEY                                            EHARDT                            141145
ENGINE MANUFACTURER           MODEL                 SERIAL NUMBER                     141145
LYCOMING                      ALF-502               LFC4                              141145
FUEL IDENT.                   FUEL FLOW PPH         MANIFOLD FUEL TEMP FAH            141145
JET-A HC RATIO 0.158           370.                 225.0                             141145
ORIFICE AIRFLOW LB/SEC        PT3 PSIA              TT3 DEG.RANKINE                   141145
  6.9                          35.0                 750.1                             141145
SIMULATED THRUST LBS          FUEL-AIR RATIO MEAS.                                    141145
 400.0                        0.0148                                                  141145
SIMULATED INLET PRESSURE PO PSIA                                                      141145
14.696                                                                                141145
SIMULATED INLET TEMPERATURE TO DEG.RANKINE                                            141145
564.7                                                                                 141145
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                                   141145
172.1                                                                                 141145
FILTER AREA .385 SI                                                                   141145
CLEAN CK SMOKE NUMBER 0                                                               141145
SMOKE NUMBER      VOL.-LITERS      FLOW-CFM PRESS.-PSIA   TEMP. DEG.FAH               141145
      0.0                3.0            0.50       11.330                74.0         141145
      0.0                4.0            0.50       11.280                74.0         141145
      2.3                7.0            0.50       11.310                74.0         141145
      2.3               11.0            0.50       11.280                75.0         141145
GASEOUS EMISSIONS                                                                     141145
                  FID          NDIR         NDIR          CHEMI        CHEMI          141145
                  UHC          CO            CO2           NO           NOX           141145
RANGE              2            2            2             1            1             141145
INSTR GAS TEMP    153.         56.          56.           64.          64.            141145
RAW VALUE MV       16.3        941.4        651.3         576.2        895.1          141145
GAS CONCEN PPM(C)  128.9        478.6        29651.3          14.2          22.1      141145
GAS CONCEN PCT    0.0129       0.0475       2.9651        0.0014       0.0022         141145
EMISSION INDEX     4.26         31.9        3101.             1.6           2.4       141145
FUEL-AIR RATIO    0.0147                                                              141145
```

```
COMBUSTOR RIG TEST                                                              171135
DATE                        DATA POINT              TEST CELL                   171135
 1/26/77                    171135                  1                           171135
INSTRUMENT OPERATOR                                 TEST OPERATOR               171135
TREMBLEY                                            EFARCT                      171135
ENGINE MANUFACTURER         MODEL                   SERIAL NUMBER               171135
LYCOMING                    ALF-502                 LF04                        171135
FUEL IDENT.                 FUEL FLOW PPH           MANIFOLD FUEL TEMP FAH      171135
JET-A HC RATIO 0.158         399.                   226.2                       171135
ORIFICE AIRFLOW LB/SEC      PT3 PSIA                TT3 DEG.RANKINE             171135
  8.1                        38.0                   747.1                       171135
SIMULATED THRUST LBS        FUEL-AIR RATIO MEAS.                                171135
 400.0                      0.0137                                              171135
SIMULATED INLET PRESSURE PO PSIA                                                171135
15.855                                                                          171135
SIMULATED INLET TEMPERATURE TO DEG.RANKINE                                      171135
564.7                                                                           171135
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                             171135
 24.9                                                                           171135
FILTER AREA .385 SI                                                             171135
CLEAN CK SMOKE NUMBER 0                                                         171135
SMOKE NUMBER        VOL.-LITERS     FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH         171135
     0.0                  3.0         0.50     11.270            73.0           171135
     2.3                  4.0         0.49     11.270            73.0           171135
     2.3                  7.0         0.50     11.270            73.0           171135
     2.3                 11.0         0.50     11.270            74.0           171135
GASEOUS EMISSIONS                                                               171135
                    FID        NDIR       NDIR       CHEMI      CHEMI           171135
                    UHC        CO         CO2        NO         NOX             171135
RANGE                1          2          2          2          2              171135
INSTR GAS TEMP      153.       55.        55.        64.        64.             171135
RAW VALUE MV         85.4      827.5      633.5      201.3      323.7           171135
GAS CONCEN PPM(C)     67.4      408.2     28736.9      19.6        31.8         171135
GAS CONCEN PCT      0.0067     0.0408     2.8737     0.0020     0.0032          171135
EMISSION INDEX       2.31       29.1      3113.        2.2        3.6           171135
FUEL-AIR RATIO      0.0142                                                      171135
```

```
COMBUSTOR RIG TEST                                                                          181145
DATE                            DATA POINT                  TEST CELL                       181145
 1/26/77                        181145                      1                               181145
INSTRUMENT OPERATOR                                         TEST OPERATOR                   181145
TREMBLEY                                                    EHARDT                          181145
ENGINE MANUFACTURER             MODEL                       SERIAL NUMBER                   181145
LYCOMING                        ALF-502                     LF04                            181145
FUEL IDENT.                     FUEL FLOW PPH               MANIFOLD FUEL TEMP FAH          181145
JET-A HC RATIO 0.158             398.                       223.1                           181145
ORIFICE AIRFLOW LB/SEC          PT3 PSIA                    TT3 DEG.RANKINE                 181145
  7.5                            38.0                       749.8                           181145
SIMULATED-THRUST LBS            FUEL-AIR RATIO MEAS.                                        181145
 400.0                          0.0147                                                      181145
SIMULATED INLET PRESSURE PO PSIA                                                            181145
15.855                                                                                      181145
SIMULATED INLET TEMPERATURE TO DEG.RANKINE                                                  181145
564.7                                                                                       181145
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                                         181145
170.6                                                                                       181145
FILTER AREA .385 SI                                                                         181145
CLEAN CK SMOKE NUMBER 0                                                                     181145
SMOKE NUMBER         VOL.-LITERS        FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH                 181145
      0.0                   3.0             0.50   11.280             74.0                  181145
      0.0                   4.0             0.50   11.260             74.0                  181145
      0.0                   7.0             0.49   11.260             74.0                  181145
      2.3                  11.0             0.50   11.260             75.0                  181145
GASEOUS EMISSIONS                                                                           181145
                   FID         NDIR         NDIR         CHEMI        CHEMI                 181145
                   UHC          CO           CO2          NO           NOX                  181145
RANGE               2           2            2            1            1                    181145
INSTR GAS TEMP     153.        57.          57.          64.          64.                   181145
RAW VALUE MV        14.9       893.6        646.0        563.3        859.1                 181145
GAS CONCEN PPM(C)  117.9        446.6        29376.8         13.9         22.2              181145
GAS CONCEN PCT     0.0118      0.0447       2.9377       0.0014       0.0022                181145
EMISSION INDEX      2.94        30.0        3104.          1.5          2.5                 181145
FUEL-AIR RATIO     0.0146                                                                   181145
                                                                                            181145
```

```
COMBUSTOR RIG TEST                                                          042135
DATE                          DATA POINT           TEST CELL                042135
 1/26/77                      042135               1                        042135
INSTRUMENT OPERATOR                                TEST OPERATOR            042135
TREMBLEY                                           EHARDT                   042135
ENGINE MANUFACTURER           MODEL                SERIAL NUMBER            042135
LYCOMING                      ALF-502              LF04                     042135
FUEL IDENT.                   FUEL FLOW PPH        MANIFOLD FUEL TEMP FAH   042135
JET-A HC RATIO 0.158           432.                228.1                    042135
ORIFICE AIRFLOW LB/SEC        PT3 PSIA             TT3 DEG.RANKINE          042135
 10.3                          40.1                784.0                    042135
SIMULATED THRUST LBS          FUEL-AIR RATIO MEAS.                          042135
 600.0                        0.0116                                        042135
SIMULATED INLET PRESSURE PO PSIA                                            042135
14.696                                                                      042135
SIMULATED INLET TEMPERATURE TO DEG.RANKINE                                  042135
544.7                                                                       042135
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                         042135
 25.0                                                                       042135
FILTER AREA .385 SI                                                         042135
CLEAN CK SMOKE NUMBER 0                                                     042135
SMOKE NUMBER      VOL.-LITERS     FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH       042135
        0.0               3.0         0.50     11.260             73.0      042135
        0.0               4.0         0.50     11.230             73.0      042135
        0.0               7.0         0.50     11.260             73.0      042135
        2.3              11.0         0.50     11.230             73.0      042135
GASEOUS EMISSIONS                                                           042135
                  FID        NDIR       NDIR        CHEMI       CHEMI       042135
                  UHC        CO         CO2         NO          NOX         042135
RANGE              2          2          2          1           1           042135
INSTR GAS TEMP    153.       55.        55.         64.         64.         042135
RAW VALUE MV       12.1      925.5      524.9       611.2       *****       042135
GAS CONCEN PPM(C)   95.4      467.3      23276.3       15.0        24.8     042135
GAS CONCEN PCT    0.0095     0.0467     2.3276      0.0015      0.0025      042135
EMISSION INDEX     4.00       39.5      3089.          2.1         3.4      042135
FUEL-AIR RATIO    0.0116                                                    042135
```

```
COMBUSTOR RIG TEST                                                          C82145
DATE                         DATA POINT           TEST CELL                 C82145
 1/26/77                     C82145               1                         C82145
INSTRUMENT OPERATOR                               TEST OPERATOR             C82145
TREMBLEY                                          EBERDT                    C82145
ENGINE MANUFACTURER          MODEL                SERIAL NUMBER             C82145
LYCOMING                     ALF-502              LF04                      C82145
FUEL IDENT.                  FUEL FLOW PPH        MANIFOLD FUEL TEMP FAH    C82145
JET-A HC RATIO 0.158          432.                225.9                     C82145
ORIFICE AIRFLOW LB/SEC       PT3 PSIA             TT3 DEG.RANKINE           C82145
 10.3                         40.1                783.9                     C82145
SIMULATED THRUST LBS         FUEL-AIR RATIO MEAS.                           C82145
 600.0                       0.0117                                         C82145
SIMULATED INLET PRESSURE PO PSIA                                            C82145
14.696                                                                      C82145
SIMULATED INLET TEMPERATURE TO DEG.RANKINE                                  C82145
544.7                                                                       C82145
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                         C82145
 49.3                                                                       C82145
FILTER AREA .385 SI                                                         C82145
CLEAN CK SMOKE NUMBER 0                                                     C82145
SMOKE NUMBER       VOL.-LITERS     FLOW-CFM PRESS.-PSIA   TEMP. DEG.FAH     C82145
       0.0                3.0         0.50    11.230               73.0     C82145
       0.0                4.0         0.50    11.300               73.0     C82145
       2.3                7.0         0.50    11.300               73.0     C82145
       2.3               11.0         0.50    11.280               73.0     C82145
GASEOUS EMISSIONS                                                           C82145
                   FID        NDIR        NDIR        CHEMI      CHEMI      C82145
                   UHC         CO          CO2         NO         NOX       C82145
RANGE               2          2           2           1          1         C82145
INSTR GAS TEMP     153.       55.         55.         64.        64.        C82145
RAW VALUE MV        13.4      536.6       525.8       574.3      539.0      C82145
GAS CONCEN PPM(C)   105.7      475.4       23319.7       14.1       23.0    C82145
GAS CONCEN PCT     0.0106     0.0475      2.3320      0.0014     0.0023     C82145
EMISSION INDEX      4.47       40.1       3087.          1.5        3.2     C82145
FUEL-AIR RATIO     0.0116                                                   C82145
```

```
COMBUSTOR RIG TEST                                                                 112145
DATA                         DATA POINT            TEST CELL                       112145
 1/26/77                     112145                1                               112145
INSTRUMENT OPERATOR                                TEST OPERATOR                   112145
TREMBLEY                                           EHARDT                          112145
ENGINE MANUFACTURER          MODEL                 SERIAL NUMBER                   112145
LYCOMING                     ALF-502               LF04                            112145
FUEL IDENT.                  FUEL FLOW PPH         MANIFOLD FUEL TEMP FAH          112145
JET-A HC RATIO 0.158          432.                 222.5                           112145
ORIFICE AIRFLOW LB/SEC       PT3 PSIA              TT3 DEG.RANKINE                 112145
 10.1                         40.1                 782.1                           112145
SIMULATED THRUST LBS         FUEL-AIR RATIO MEAS.                                  112145
 600.0                       0.0119                                                112145
SIMULATED INLET PRESSURE PO PSIA                                                   112145
14.696                                                                             112145
SIMULATED INLET TEMPERATURE TO DEG.RANKINE                                         112145
544.7                                                                              112145
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                                112145
101.7                                                                              112145
FILTER AREA .385 SI                                                                112145
CLEAN CK SMOKE NUMBER 0                                                            112145
SMOKE NUMBER       VOL.-LITERS      FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH            112145
         0.0                3.0        0.50     11.280               72.0          112145
         0.0                4.0        0.50     11.300               72.0          112145
         0.0                7.0        0.50     11.250               72.0          112145
         2.3               11.0        0.50     11.250               72.0          112145
GASEOUS EMISSIONS                                                                  112145
                   FID        NDIR       NDIR       CHEMI      CHEMI               112145
                   UHC        CO         CO2        NO         NOX                 112145
RANGE               2          2          2          1          1                  112145
INSTR GAS TEMP     153.       53.        53.        64.        64.                 112145
RAW VALUE MV        15.9      547.2      530.5      513.8      829.9               112145
GAS CONCEN PPM(C)   126.0      483.8      23556.7       12.6       20.3            112145
GAS CONCEN PCT     0.0126     0.0484     2.3557     0.0013     0.0020              112145
EMISSION INDEX      5.22       40.3      3084.        1.7        2.8               112145
FUEL-AIR RATIO     0.0117                                                          112145
```

```
COMBUSTOR RIG TEST                                                                   132145
DATE                          DATA POINT          TEST CELL                          132145
 1/26/77                      132145              1                                  132145
INSTRUMENT OPERATOR                               TEST OPERATOR                      132145
TREMBLEY                                          EFARDT                             132145
ENGINE MANUFACTURER           MODEL               SERIAL NUMBER                      132145
LYCOMING                      ALF-502             LF04                               132145
FUEL IDENT.                   FUEL FLOW PPH       MANIFOLD FUEL TEMP FAH             132145
JET-A HC RATIO 0.158           432.               224.7                              132145
ORIFICE AIRFLOW LB/SEC        PT3 PSIA            TT3 DEG.RANKINE                    132145
  9.6                          40.2               783.0                              132145
SIMULATED THRUST LBS          FUEL-AIR RATIO MEAS.                                   132145
 600.0                        0.0125                                                 132145
SIMULATED INLET PRESSURE PO PSIA                                                     132145
14.696                                                                               132145
SIMULATED INLET TEMPERATURE TO DEG.RANKINE                                           132145
544.7                                                                                132145
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                                  132145
171.8                                                                                132145
FILTER AREA .385 SI                                                                  132145
CLEAN CK SMOKE NUMBER 0                                                              132145
SMOKE NUMBER         VOL.-LITERS      FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH            132145
      0.0                   3.0           0.52     11.230              72.0          132145
      0.0                   4.0           0.50     11.260              72.0          132145
      0.0                   7.0           0.50     11.260              72.0          132145
      2.3                  11.0           0.50     11.260              72.0          132145
GASEOUS EMISSIONS                                                                    132145
                  FID        NDIR        NDIR        CHEMI       CHEMI               132145
                  UHC         CO          CO2         NO          NOX                132145
RANGE              2          3           2           1           1                  132145
INSTR GAS TEMP    153.        53.         53.         64.         64.                132145
RAW VALUE MV       20.6       419.5       536.4       448.6       722.6              132145
GAS CONCEN PPM(C)  163.7       523.7       23852.3        11.0        17.7           132145
GAS CONCEN PCT    0.0164      0.0524      2.3852      0.0011      0.0018             132145
EMISSION INDEX     6.67        43.0       3075.           1.5         2.4            132145
FUEL-AIR RATIO    0.0119                                                             132145
```

```
COMBUSTOR RIG TEST                                                                   212135
DATE                         DATA POINT               TEST CELL                      212135
 1/26/77                     212135                   1                              212135
INSTRUMENT OPERATOR                                   TEST OPERATOR                  212135
TREMBLEY                                              EHARDT                         212135
ENGINE MANUFACTURER          MODEL                    SERIAL NUMBER                  212135
LYCOMING                     ALF-502                  LF04                           212135
FUEL IDENT.                  FUEL FLOW PPH            MANIFOLD FUEL TEMP FAH         212135
JET-A HC RATIO 0.158          385.                    227.9                          212135
ORIFICE AIRFLOW LB/SEC       PT3 PSIA                 TT3 DEG.RANKINE                212135
  8.5                         34.8                    811.3                          212135
SIMULATED THRUST LBS         FUEL-AIR RATIO MEAS.                                    212135
 600.0                       0.0125                                                  212135
SIMULATED INLET PRESSURE PO PSIA                                                     212135
12.761                                                                               212135
SIMULATED INLET TEMPERATURE TO DEG.RANKINE                                           212135
564.7                                                                                212135
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                                  212135
 25.2                                                                                212135
FILTER AREA .385 SI                                                                  212135
CLEAN CK SMOKE NUMBER 0                                                              212135
SMOKE NUMBER          VOL.-LITERS      FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH           212135
         0.0                    3.0         0.50     11.270              74.0        212135
         0.0                    4.0         0.49     11.240              74.0        212135
         0.0                    7.0         0.50     11.270              74.0        212135
         2.3                   11.0         0.50     11.240              74.0        212135
GASEOUS EMISSIONS                                                                    212135
                      FID         NDIR        NDIR        CHEMI       CHEMI          212135
                      UHC          CO          CO2         NO          NOX           212135
RANGE                  1           2           2           2           2             212135
INSTR GAS TEMP        153.        63.         63.         64.         64.            212135
RAW VALUE MV           77.4       855.0       570.7       192.0       294.7          212135
GAS CONCEN PPM(C)       61.4       447.2       25630.5       18.8        28.9        212135
GAS CONCEN PCT        0.0061      0.0447      2.5631      0.0019      0.0029         212135
EMISSION INDEX         2.35        34.5       3103.          2.4         3.7         212135
FUEL-AIR RATIO        0.0127                                                         212135
```

```
COMBUSTOR RIG TEST                                                          222145
DATE                          DATA POINT              TEST CELL             222145
 1/26/77                      222145                  1                     222145
INSTRUMENT OPERATOR                                   TEST OPERATOR         222145
TREMBLEY                                              EFAFCT                222145
ENGINE MANUFACTURER           MODEL                   SERIAL NUMBER         222145
LYCOMING                      ALF-502                 LFC4                  222145
FUEL IDENT.                   FUEL FLOW PPH           MANIFOLD FUEL TEMP FAH 222145
JET-A HC RATIO 0.158           385.                   226.9                 222145
ORIFICE AIRFLOW LB/SEC        PT3 PSIA                TT3 DEG.RANKINE       222145
  8.1                          34.8                   810.3                 222145
SIMULATED THRUST LBS          FUEL-AIR RATIO MEAS.                          222145
 600.0                        0.0131                                        222145
SIMULATED INLET PRESSURE PO PSIA                                            222145
12.761                                                                      222145
SIMULATED INLET TEMPERATURE TO DEG.RANKINE                                  222145
564.7                                                                       222145
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                         222145
173.4                                                                       222145
FILTER AREA .385 SI                                                         222145
CLEAN CK SMOKE NUMBER 0                                                     222145
SMOKE NUMBER        VOL.-LITERS     FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH     222145
      0.0                   3.0         0.50   11.260             73.0      222145
      0.0                   4.0         0.50   11.230             73.0      222145
      0.0                   7.0         0.50   11.260             73.0      222145
      2.3                  11.0         0.50   11.230             73.0      222145
GASEOUS EMISSIONS                                                           222145
                    FID       NDIR       NDIR       CHEMI      CHEMI        222145
                    UHC       CO         CO2        NO         NOX          222145
RANGE                2        2          2          1          1            222145
INSTR GAS TEMP      153.      57.        57.        64.        64.          222145
RAW VALUE MV         15.8     562.7      577.4      517.6      792.3        222145
GAS CONCEN PPM(C)   126.1      496.1      25972.1      12.9       19.6      222145
GAS CONCEN PCT      0.0126    0.0456     2.5972     0.0013     0.0020       222145
EMISSION INDEX       4.74      37.6      3090.         1.6        2.4       222145
FUEL-AIR RATIO      0.0129                                                  222145
```

```
COMBUSTOR RIG TEST                                                          052135
DATE                         DATA POINT          TEST CELL                  052135
 1/26/77                     052135              1                          052135
INSTRUMENT OPERATOR                              TEST OPERATOR              052135
TREMBLEY                                         EHARDT                     052135
ENGINE MANUFACTURER          MODEL               SERIAL NUMBER              052135
LYCOMING                     ALF-502             LFC4                       052135
FUEL IDENT.                  FUEL FLOW PPH       MANIFOLD FUEL TEMP FAH     052135
JET-A HC RATIO 0.158          443.               223.7                      052135
ORIFICE AIRFLOW LB/SEC       PT3 PSIA            TT3 DEG.RANKINE            052135
 10.1                         40.1               810.8                      052135
SIMULATED THRUST LBS         FUEL-AIR RATIO MEAS.                           052135
 600.0                       0.0121                                         052135
SIMULATED INLET PRESSURE P0 PSIA                                            052135
14.696                                                                      052135
SIMULATED INLET TEMPERATURE T0 DEG.RANKINE                                  052135
564.7                                                                       052135
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                         052135
 25.1                                                                       052135
FILTER AREA .385 SI                                                         052135
CLEAN CK SMOKE NUMBER 0                                                     052135
SMOKE NUMBER        VOL.-LITERS     FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH     052135
          0.0                3.0        0.50    11.300             72.0     052135
          0.0                4.0        0.50    11.300             72.0     052135
          0.0                7.0        0.50    11.300             73.0     052135
          2.3               11.0        0.50    11.250             72.0     052135
GASEOUS EMISSIONS                                                           052135
                    FID         NDIR        NDIR        CHEMI      CHEMI    052135
                    UHC         CO          CO2         NO         NOX      052135
RANGE               1           2           2           2          2        052135
INSTR GAS TEMP      153.        57.         57.         64.        64.      052135
RAW VALUE MV         90.2       878.6       546.2       190.3      284.9    052135
GAS CONCEN PPM(C)      71.6       437.8      24386.7       18.5       27.8  052135
GAS CONCEN PCT      0.0072      0.0438      2.4387      0.0019     0.0028   052135
EMISSION INDEX       2.88        35.4       3099.          2.5        3.7   052135
FUEL-AIR RATIO      0.0121                                                  052135
```

```
COMBUSTOR RIG TEST                                                                 092145
DATE                          DATA POINT             TEST CELL                     092145
 1/26/77                      092145                 1                             092145
INSTRUMENT OPERATOR                                  TEST OPERATOR                 092145
TREMBLEY                                             EFARCT                        092145
ENGINE MANUFACTURER           MODEL                  SERIAL NUMBER                 092145
LYCOMING                      ALF-502                LF04                          092145
FUEL IDENT.                   FUEL FLOW PPH          MANIFOLD FUEL TEMP FAH        092145
JET-A HC RATIO 0.158           442.                  223.1                         092145
ORIFICE AIRFLOW LB/SEC        PT3 PSIA               TT3 DEG.RANKINE               092145
 10.0                          40.1                  810.4                         092145
SIMULATED THRUST LBS          FUEL-AIR RATIO MEAS.                                 092145
 600.0                        0.0122                                               092145
SIMULATED INLET PRESSURE PC PSIA                                                   092145
14.696                                                                             092145
SIMULATED INLET TEMPERATURE TC DEG.RANKINE                                         092145
564.7                                                                              092145
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                                092145
 49.5                                                                              092145
FILTER AREA .385 SI                                                                092145
CLEAN CK SMOKE NUMBER 0                                                            092145
SMOKE NUMBER       VOL.-LITERS    FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH              092145
      0.0                 3.0          0.50     11.310             72.0            092145
      0.0                 4.0          0.49     11.230             72.0            092145
      0.0                 7.0          0.50     11.260             72.0            092145
      2.3                11.0          0.50     11.260             72.0            092145
GASEOUS EMISSIONS                                                                  092145
                   FID        NDIR        NDIR        CHEMI      CHEMI             092145
                   UHC         CO          CO2         NO         NOX              092145
RANGE               1          2           2           2          2                092145
INSTR GAS TEMP     153.       57.         57.         64.        64.               092145
RAW VALUE MV       103.3      887.5       547.0       172.9      264.7             092145
GAS CONCEN PPM(C)    82.1      443.1       24426.1       16.8       25.9           092145
GAS CONCEN PCT     0.0082     0.0443      2.4426      0.0017     0.0026            092145
EMISSION INDEX      3.29       35.8       3057.          2.2        3.4            092145
FUEL-AIR RATIO     0.0121                                                          092145
```

```
COMBUSTOR RIG TEST                                                                      122145
DATE                          DATA POINT             TEST CELL                          122145
 1/26/77                      122145                 1                                  122145
INSTRUMENT OPERATOR                                  TEST OPERATOR                      122145
TREMBLEY                                             EHARDT                             122145
ENGINE MANUFACTURER           MODEL                  SERIAL NUMBER                      122145
LYCOMING                      ALF-502                LF04                               122145
FUEL IDENT.                   FUEL FLOW PPH          MANIFOLD FUEL TEMP FAH             122145
 JET-A HC RATIO 0.1K,          442.                  224.1                              122145
ORIFICE AIRFLOW LB/SEC        PT3 PSIA               TT3 DEG.RANKINE                    122145
  9.9                          40.1                  810.6                              122145
SIMULATED THRUST LBS          FUEL-AIR RATIO MEAS.                                      122145
 600.0                        0.0124                                                    122145
SIMULATED INLET PRESSURE PO PSIA                                                        122145
14.696                                                                                  122145
SIMULATED INLET TEMPERATURE TO DEG.RANKINE                                              122145
564.7                                                                                   122145
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                                     122145
103.1                                                                                   122145
FILTER AREA .385 SI                                                                     122145
CLEAN CK SMOKE NUMBER 0                                                                 122145
SMOKE NUMBER      VOL.-LITERS     FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH                   122145
        0.0                3.0        0.50     11.260                72.0               122145
        0.0                4.0        0.50     11.260                72.0               122145
        0.0                7.0        0.52     11.260                72.0               122145
        2.3               11.0        0.51     11.280                73.0               122145
GASEOUS EMISSIONS                                                                       122145
                   FID        NDIR        NDIR       CHEMI       CHEMI                  122145
                   UHC        CO          CO2        NO          NOX                    122145
RANGE               2          2           2          1           1                     122145
INSTR GAS TEMP     153.       55.         55.        64.         64.                    122145
RAW VALUE MV        12.4      904.9       549.0      594.3       921.5                  122145
GAS CONCEN PPM(C)   57.8      453.8     24531.0         14.7        22.7                122145
GAS CONCEN PCT     0.0058     0.0454      2.4531     0.0015      0.0023                 122145
EMISSION INDEX     3.90       36.4       3055.          1.9         3.0                 122145
FUEL-AIR RATIO     0.0122                                                               122145
```

Reproduced from best available copy.

```
COMBUSTOR RIG TEST                                                                 142145
DATE                          DATA POINT          TEST CELL                        142145
 1/26/77                      142145              1                                142145
INSTRUMENT OPERATOR                               TEST OPERATOR                    142145
TREMBLEY                                          EHARDT                           142145
ENGINE MANUFACTURER           MODEL               SERIAL NUMBER                    142145
LYCOMING                      ALF-502             LF04                             142145
FUEL IDENT.                   FUEL FLOW PPH       MANIFOLD FUEL TEMP FAH           142145
JET-A HC RATIO 0.158           442.               223.6                            142145
ORIFICE AIRFLOW LB/SEC        PT3 PSIA            TT3 DEG.RANKINE                  142145
  9.6                          40.1               811.0                            142145
SIMULATED THRUST LBS          FUEL-AIR RATIO MEAS.                                 142145
 600.0                        0.0128                                               142145
SIMULATED INLET PRESSURE PO PSIA                                                   142145
14.696                                                                             142145
SIMULATED INLET TEMPERATURE TO DEG.RANKINE                                         142145
564.7                                                                              142145
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                                142145
166.0                                                                              142145
FILTER AREA .385 SI                                                                142145
CLEAN CK SMOKE NUMBER 0                                                            142145
SMOKE NUMBER          VOL.-LITERS     FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH          142145
         0.0                 3.0          0.50     11.260              72.0        142145
         0.0                 4.0          0.49     11.240              72.C        142145
         0.0                 7.0          0.50     11.240              73.0        142145
         2.3                11.0          0.50     11.260              73.0        142145
GASEOUS EMISSIONS                                                                  142145
                      FID        NDIR        NDIR        CHEMI       CHEMI         142145
                      UHC         CO          CO2         NO          NOX          142145
RANGE                  2          2           2           1           1            142145
INSTR GAS TEMP        153.       54.         54.         64.         64.           142145
RAW VALUE MV           15.7      935.9       550.7       521.3       796.0         142145
GAS CONCEN PPM(C)     124.9      474.9     24617.4        12.9        15.7         142145
GAS CONCEN PCT        0.0125     0.0475     2.4617      0.0013      0.0020         142145
EMISSION INDEX         4.96       37.93     3089.          1 .7         2.6        142145
FUEL-AIR RATIO        0.0123                                                       142145
```

Reproduced from best available copy.

```
                                                                                      172135
COMBUSTOR RIG TEST                                                                    172135
DATE                       DATA POINT              TEST CELL                          172135
 3/25/77                   172135                  1                                  172135
INSTRUMENT OPERATOR                                TEST OPERATOR                      172135
TREMBLEY                                           EHARDT                             172135
ENGINE MANUFACTURER        MODEL                   SERIAL NUMBER                      172135
LYCOMING                   ALF-502                 LF04                               172135
FUEL IDENT.                FUEL FLOW PPH           MANIFOLD FUEL TEMP FAH             172135
JET-A HC RATIO 0.152        478.                   226.4                              172135
ORIFICE AIRFLOW LB/SEC     PT3 PSIA                TT3 DEG.RANKINE                    172135
 10.9                       43.4                   811.5                              172135
SIMULATED THRUST LBS       FUEL-AIR RATIO MEAS.                                       172135
 600.0                     0.0122                                                     172135
SIMULATED INLET PRESSURE PO PSIA                                                      172135
15.855                                                                                172135
SIMULATED INLET TEMPERATURE TO DEG.RANKINE                                            172135
564.7                                                                                 172135
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                                   172135
 26.7                                                                                 172135
FILTER AREA .385 SI                                                                   172135
CLEAN CK SMOKE NUMBER 0                                                               172135
SMOKE NUMBER        VOL.-LITERS      FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH              172135
        0.0                 3.0          0.51      11.240              78.0           172135
        4.5                 4.0          0.52      11.461              78.0           172135
        2.3                 7.0          0.51      11.240              78.0           172135
        2.3                11.0          0.51      11.240              77.0           172135
GASEOUS EMISSIONS                                                                     172135
                    FID          NDIR         NDIR         CHEMI        CHEMI         172135
                    UHC           CO           CO2          NO           NOX          172135
RANGE                1            2            2            1            2            172135
INSTR GAS TEMP      150.         61.          61.          65.          65.           172135
RAW VALUE MV         74.4        791.1        556.9        677.7        287.6         172135
GAS CONCEN PPM(C)    57.2         395.9       24199.0         16.6         28.9       172135
GAS CONCEN PCT      0.0057       0.0356       2.4199       0.0017       0.0029        172135
EMISSION INDEX       2.32         32.5        3122.           2.2          3.9        172135
FUEL-AIR RATIO      0.0119
```

```
COMBUSTOR RIG TEST                                                                   182155
DATE                             DATA POINT            TEST CELL                     182155
 3/25/77                         182155                1                             182155
INSTRUMENT OPERATOR                                    TEST OPERATOR                 182155
TREMBLEY                                               EHARDT                        182155
ENGINE MANUFACTURER              MODEL                 SERIAL NUMBER                 182155
LYCOMING                         ALF-502               LF04                          182155
FUEL IDENT.                      FUEL FLOW PPH         MANIFOLD FUEL TEMP FAH        182155
JET-A HC RATIO 0.152              478.                 224.7                         182155
ORIFICE AIRFLOW LB/SEC           PT3 PSIA              TT3 DEG.RANKINE               182155
 10.4                             43.3                 812.5                         182155
SIMULATED THRUST LBS             FUEL-AIR RATIO MEAS.                                182155
 600.0                           0.0127                                              182155
SIMULATED INLET PRESSURE P0 PSIA                                                     182155
15.855                                                                               182155
SIMULATED INLET TEMPERATURE T0 DEG.RANKINE                                           182155
564.7                                                                                182155
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                                  182155
176.2                                                                                182155
FILTER AREA .385 ST                                                                  182155
CLEAN CK SMOKE NUMBER 0                                                              182155
SMOKE NUMBER          VOL.-LITERS      FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH           182155
         2.3                 3.0           0.49    11.188             82.0           182155
         2.3                 4.0           0.50    11.237             82.0           182155
         2.3                 7.0           0.50    11.213             81.0           182155
         2.3                11.0           0.52    11.188             82.0           182155
 GASEOUS EMISSIONS                                                                   182155
                   FID        NDIR        NDIR        CHEMI       CHEMI              182155
                   UHC         CO          CO2         NO          NOX               182155
RANGE               2          2           2           1           1                 182155
INSTR GAS TEMP     150.       61.         61.         64.         64.                182155
RAW VALUE MV        18.5      531.0       564.3       477.3       789.1              182155
GAS CONCEN PPM(C)  146.0       483.8      24562.8        12.2        20.0            182155
GAS CONCEN PCT     0.0146     0.0484      2.4563      0.0012      0.0020             182155
EMISSION INDEX      5.80       38.9       3101.          1.6         2.6             182155
FUEL-AIR RATIO     0.0122                                                            182155
```

```
COMBUSTOR RIG TEST                                                        198144
DATE                          DATA POINT          TEST CELL               198144
 3/ 2/77                      198144              1                       198144
INSTRUMENT OPERATOR                               TEST OPERATOR           198144
TREMBLEY                                          EHARDT                  198144
ENGINE MANUFACTURER           MODEL               SERIAL NUMBER           198144
LYCOMING                      ALF-502             LF04                    198144
FUEL IDENT.                   FUEL FLOW PPH       MANIFOLD FUEL TEMP FAH  198144
JET-A HC RATIO 0.158          1198.               226.2                   198144
ORIFICE AIRFLOW LB/SEC        PT3 PSIA            TT3 DEG.RANKINE         198144
 19.3                          80.3               852.7                   198144
SIMULATED THRUST LBS          FUEL-AIR RATIO MEAS.                        198144
6500.0                        0.0182                                      198144
SIMULATED INLET PRESSURE PC PSIA                                          198144
12.761                                                                    198144
SIMULATED INLET TEMPERATURE TC DEG.RANKINE                                198144
478.7                                                                     198144
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                       198144
 23.6                                                                     198144
FILTER AREA .385 SI                                                       198144
CLEAN CK SMOKE NUMBER 0                                                   198144
SMOKE NUMBER        VOL.-LITERS     FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH   198144
         8.8                3.0         0.50     11.716            70.0   198144
        10.9                4.0         0.50     11.692            70.0   198144
        18.7                7.0         0.50     11.716            70.0   198144
        22.4               11.0         0.50     11.716            72.0   198144
GASEOUS EMISSIONS                                                         198144
                    FID        NDIR       NDIR       CHEMI      CHEMI     198144
                    HC          CO         CO2        NO         NOX      198144
RANGE                1          2          2          2          2        198144
INSTR GAS TEMP      154.       52.        52.        64.        64.       198144
RAW VALUE MV          5.5      354.7      807.2      413.9      519.2     198144
GAS CONCEN PPM(C)      4.8      147.2     37580.2        41.7       52.5  198144
GAS CONCEN PCT      0.0005     0.0147     3.7580     0.0042     0.0052    198144
EMISSION INDEX      0.13         7.9      3151.         3.7        4.6    198144
FUEL-AIR RATIO      0.0184                                                198144
```

```
COMBUSTOR RIG TEST                                                              193134
DATE                        DATA POINT              TEST CELL                   193134
 3/ 2/77                    193134                  1                           193134
INSTRUMENT OPERATOR                                 TEST OPERATOR               193134
TREMBLEY                                            EHARDT                      193134
ENGINE MANUFACTURER         MODEL                   SERIAL NUMBER               193134
LYCOMING                    ALF-502                 LF04                        193134
FUEL IDENT.                 FUEL FLOW PPH           MANIFOLD FUEL TEMP FAH      193134
JET-A HC RATIO 0.158         659.                   225.3                       193134
ORIFICE AIRFLOW LB/SEC      PT3 PSIA                TT3 DEG.RANKINE             193134
 16.2                        65.4                   835.1                       193134
SIMULATED THRUST LBS        FUEL-AIR RATIO MEAS.                                193134
1950.0                      0.0113                                              193134
SIMULATED INLET PRESSURE PO PSIA                                                193134
12.761                                                                          193134
SIMULATED INLET TEMPERATURE TO DEG.RANKINE                                      193134
478.7                                                                           193134
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                             193134
 24.0                                                                           193134
FILTER AREA .385 SI                                                             193134
CLEAN CK SMOKE NUMBER 0                                                         193134
SMOKE NUMBER        VOL.-LITERS     FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH         193134
        2.3                 3.0          0.50     11.666           74.0         193134
        4.5                 4.0          0.52     11.666           74.0         193134
       10.9                 7.0          0.51     11.691           74.0         193134
       14.9                11.0          0.51     11.715           74.0         193134
GASEOUS EMISSIONS                                                               193134
                    FID        NDIR        NDIR        CHEMI       CHEMI        193134
                    UHC        CO          CO2         NO          NOX          193134
RANGE                1          2           2           2           2           193134
INSTR GAS TEMP      154.       55.         55.         64.         64.          193134
RAW VALUE MV         41.4      595.6       516.6       207.7       317.8        193134
GAS CONCEN PPM(C)      35.4      264.9      22668.1        20.4        31.4     193134
GAS CONCEN PCT      0.0035     0.0265      2.2668      0.0020      0.0031       193134
EMISSION INDEX        1.54       23.2      3123.           2.9         4.5      193134
FUEL-AIR RATIO      0.0112                                                      193134
```

```
COMBUSTOR RIG TEST                                                               C13144
DATE                       DATA POINT             TEST CELL                      C13144
 3/25/77                   C13144                 1                              C13144
INSTRUMENT OPERATOR                               TEST OPERATOR                  C13144
TREMBLEY                                          EHARDT                         C13144
ENGINE MANUFACTURER        MODEL                  SERIAL NUMBER                  C13144
LYCOMING                   ALF-502                LF04                           C13144
FUEL IDENT.                FUEL FLOW PPH          MANIFOLD FUEL TEMP FAH         C13144
JET-A HC RATIO 0.152        738.                  224.1                          C13144
ORIFICE AIRFLOW LB/SEC     PT3 PSIA               TT3 DEG.RANKINE                C13144
 18.6                       75.0                  832.7                          C13144
SIMULATED THRUST LBS       FUEL-AIR RATIO MEAS.                                  C13144
1950.0                     0.0110                                                C13144
SIMULATED INLET PRESSURE PO PSIA                                                 C13144
14.696                                                                           C13144
SIMULATED INLET TEMPERATURE TO DEG.RANKINE                                       C13144
478.7                                                                            C13144
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                              C13144
 26.5                                                                            C13144
FILTER AREA .385 SI                                                              C13144
CLEAN CK SMOKE NUMBER 0                                                          C13144
SMOKE NUMBER         VOL.-LITERS      FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH        C13144
        4.5                 2.0           0.48     11.341             79.0       C13144
        4.5                 4.0           0.48     11.341             79.0       C13144
       10.9                 7.0           0.50     11.292             79.0       C13144
       14.9                11.0           0.48     11.243             79.0       C13144
GASEOUS EMISSIONS                                                                C13144
                     FID         NDIR        NDIR        CHEMI       CHEMI       C13144
                     UHC         CO          CO2         NO          NOX         C13144
RANGE                 1          2           2           1           2           C13144
INSTR GAS TEMP       150.        59.         59.         65.         64.         C13144
RAW VALUE MV          42.2       520.3       513.4       810.0       317.3       C13144
GAS CONCEN PPM(C)      33.6       230.3       22069.5        20.5        32.6    C13144
GAS CONCEN PCT       0.0034      0.0230      2.2070      0.0020      0.0033      C13144
EMISSION INDEX        1.50       20.9        3143.          3.0         4.9      C13144
FUEL-AIR RATIO       0.0109                                                      C13144
```

```
COMBUSTOR RIG TEST
DATE                        DATA POINT            TEST CELL                   153144
 3/25/77                    153144                1                           153144
INSTRUMENT OPERATOR                               TEST OPERATOR               153144
TREMBLEY                                          EHARDT                      153144
ENGINE MANUFACTURER         MODEL                 SERIAL NUMBER               153144
LYCOMING                    ALF-502               LF04                        153144
FUEL IDENT.                 FUEL FLOW PPH         MANIFOLD FUEL TEMP FAH      153144
JET-A HC RATIO 0.152         807.                 225.3                       153144
ORIFICE AIRFLOW LB/SEC      PT3 PSIA              TT3 DEG.RANKINE             153144
 20.2                        81.1                 834.2                       153144
SIMULATED THRUST LBS        FUEL-AIR RATIO MEAS.                              153144
1950.0                      0.0111                                            153144
SIMULATED INLET PRESSURE PO PSIA                                              153144
15.855                                                                        153144
SIMULATED INLET TEMPERATURE TO DEG.RANKINE                                    153144
478.7                                                                         153144
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                           153144
 26.6                                                                         153144
FILTER AREA .385 SI                                                           153144
CLEAN CK SMOKE NUMBER 0                                                       153144
SMOKE NUMBER         VOL.-LITERS      FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH     153144
        2.3                  3.0          0.50    11.340              74.0    153144
       10.9                  4.0          0.50    11.340              74.0    153144
       14.9                  7.0          0.50    11.340              74.0    153144
       16.8                 11.0          0.51    11.340              74.0    153144
GASEOUS EMISSIONS                                                             153144
                    FID        NDIR       NDIR        CHEMI      CHEMI        153144
                    UHC         CO         CO2        NO          NOX         153144
RANGE               1          2          2           2          2            153144
INSTR GAS TEMP      150.       59.        59.         64.        64.          153144
RAW VALUE MV         35.8      506.1      518.7       226.8      326.3        153144
GAS CONCEN PPM(C)     30.2       221.3     22320.8        22.9        33.2    153144
GAS CONCEN PCT      0.0030     0.0221     2.2321      0.0023     0.0033       153144
EMISSION INDEX       1.34       19.8      3145.          3.4        4.9       153144
FUEL-AIR RATIO      0.0109                                                    153144
```

```
COMBUSTOR RIG TEST                                                              023134
DATE                       DATA POINT           TEST CELL                       023134
 3/25/77                   023134               1                               023134
INSTRUMENT OPERATOR                             TEST OPERATOR                   023134
TREMBLEY                                        EHARDT                          023134
ENGINE MANUFACTURER        MODEL                SERIAL NUMBER                   023134
LYCOMING                   ALF-502              LF04                            023134
FUEL IDENT.                FUEL FLOW PPH        MANIFOLD FUEL TEMP FAH          023134
JET-A HC RATIO 0.152        758.                226.8                           023134
ORIFICE AIRFLOW LB/SEC     PT3 PSIA             TT3 DEG.RANKINE                 023134
 18.3                       75.0                866.0                           023134
SIMULATED THRUST LBS       FUEL-AIR RATIO MEAS.                                 023134
1950.0                     0.0115                                               023134
SIMULATED INLET PRESSURE PO PSIA                                                023134
14.696                                                                          023134
SIMULATED INLET TEMPERATURE TO DEG.RANKINE                                      023134
498.7                                                                           023134
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                             023134
 25.1                                                                           023134
FILTER AREA .385 SI                                                             023134
CLEAN CK SMOKE NUMBER 0                                                         023134
SMOKE NUMBER          VOL.-LITERS     FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH       023134
        2.3                  3.0          0.50      11.335            80.0      023134
        6.7                  4.0          0.50      11.335            80.0      023134
        6.7                  7.0          0.50      11.335            80.0      023134
       12.9                 11.0          0.48      11.286            80.0      023134
GASEOUS EMISSIONS                                                               023134
                    FID        NDIR       NDIR        CHEMI       CHEMI         023134
                    UHC         CO         CO2         NO          NOX          023134
RANGE                1          2          2           2           2            023134
INSTR GAS TEMP      150.       61.        61.         65.         64.           023134
RAW VALUE MV         28.8      503.5      539.9       247.3       358.4         023134
GAS CONCEN PPM(C)     28.8      221.2      23300.8        25.4        36.8      023134
GAS CONCEN PCT      0.0029     0.0221     2.3301      0.0025      0.0037        023134
EMISSION INDEX       1.22      19.0       3147.          3.6         5.2        023134
FUEL-AIR RATIO      0.0114                                                      023134
```

```
COMBUSTOR RIG TEST                                                          063144
DATE                         DATA POINT          TEST CELL                  063144
 3/25/77                     063144              1                          063144
INSTRUMENT OPERATOR                              TEST OPERATOR              063144
TREMBLEY                                         EHARDT                     063144
ENGINE MANUFACTURER          MODEL               SERIAL NUMBER              063144
LYCOMING                     ALF-502             LFC4                       063144
FUEL IDENT.                  FUEL FLOW PPH       MANIFOLD FUEL TEMP FAH     063144
JET-A HC RATIO 0.152          767.               226.8                      063144
ORIFICE AIRFLOW LB/SEC       PT3 PSIA            TT3 DEG.RANKINE            063144
 18.3                         75.0               867.2                      063144
SIMULATED THRUST LBS         FUEL-AIR RATIO MEAS.                           063144
1950.0                       0.0116                                         063144
SIMULATED INLET PRESSURE PO PSIA                                            063144
14.696                                                                      063144
SIMULATED INLET TEMPERATURE TO DEG.RANKINE                                  063144
498.7                                                                       063144
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                         063144
 35.4                                                                       063144
FILTER AREA .385 SI                                                         063144
CLEAN CK SMOKE NUMBER 0                                                     063144
SMOKE NUMBER       VOL.-LITERS     FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH      063144
      4.6                 3.0          0.50     11.285             78.0     063144
      6.7                 4.0          0.50     11.336             78.0     063144
      8.8                 7.0          0.50     11.336             78.0     063144
     12.9                11.0          0.48     11.287             79.0     063144
GASEOUS EMISSIONS                                                           063144
                   FID         NDIR         NDIR         CHEMI        CHEMI    063144
                   UHC          CO          CO2           NO          NOX      063144
RANGE               1            2            2            2            2      063144
INSTR GAS TEMP     150.         59.          59.          64.          64.     063144
RAW VALUE MV        31.9       510.9        537.8        239.9        346.7    063144
GAS CONCEN PPM(C)    32.1       225.1      23198.0         24.6         35.6   063144
GAS CONCEN PCT     0.0032      0.0225       2.3158       0.0025       0.0036   063144
EMISSION INDEX      1.37        19.4        3146.          3.5          5.0    063144
FUEL-AIR RATIO     0.0113                                                   063144
```

```
                                                                                  203144
COMBUSTOR RIG TEST                                                                203144
DATE                       DATA POINT              TEST CELL                      203144
 3/25/77                   203144                  1                              203144
INSTRUMENT OPERATOR                                TEST OPERATOR                  203144
TREMBLEY                                           PEARCT                         203144
ENGINE MANUFACTURER        MODEL                   SERIAL NUMBER                  203144
LYCOMING                   ALF-502                 LF04                           203144
FUEL IDENT.                FUEL FLOW PPH           MANIFOLD FUEL TEMP FAH         203144
JET-A HC RATIO 0.152        690.                   226.4                          203144
ORIFICE AIRFLOW LB/SEC     PT3 PSIA                TT3 DEG.RANKINE                203144
 15.7                       65.0                   900.8                          203144
SIMULATED THRUST LBS       FUEL-AIR RATIO MEAS.                                   203144
1950.0                     0.0122                                                 203144
SIMULATED INLET PRESSURE PO PSIA                                                  203144
12.761                                                                            203144
SIMULATED INLET TEMPERATURE TO DEG.RANKINE                                         203144
518.7                                                                             203144
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                               203144
 53.9                                                                             203144
FILTER AREA .385 SI                                                               203144
CLEAN CK SMOKE NUMBER 0                                                           203144
SMOKE NUMBER       VOL.-LITERS      FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH           203144
        2.3                3.0          0.50      11.394             75.0         203144
        0.0                4.0          0.50      11.394             75.0         203144
        4.5                7.0          0.50      11.345             75.0         203144
        8.8               11.0          0.50      11.394             75.0         203144
 GASEOUS EMISSIONS                                                                203144
                   FID          NDIR         NDIR          CHEMI      CHEMI       203144
                   UHC          CO           CO2           NO         NOX         203144
 RANGE              1           2            2             2          2           203144
 INSTR GAS TEMP    150.         56.          56.           64.        64.         203144
 RAW VALUE MV       36.4        533.8        562.8         248.3      353.0       203144
 GAS CONCEN PPM(C)    32.2        236.8        24477.5         25.2       35.9    203144
 GAS CONCEN PCT    0.0022       0.0237       2.4478        0.0025     0.0036      203144
 EMISSION INDEX     1.30        19.4         3146.            3.4        4.8      203144
 FUEL-AIR RATIO    0.0120                                                         203144
```

```
COMBUSTOR RIG TEST
DATE                                                                       033134
 3/25/77                      DATA POINT              TEST CELL            033134
INSTRUMENT OPERATOR           033134                  1                    033134
TREMBLEY                                              TEST OPERATOR        033134
ENGINE MANUFACTURER                                   EHARDT               033134
LYCOMING                      MODEL                   SERIAL NUMBER        033134
                              ALF-502                 LF04                 033134
FUEL IDENT.                   FUEL FLOW PPH           MANIFOLD FUEL TEMP FAH 033134
JET-A HC RATIO 0.152           787.                   225.8                033134
ORIFICE AIRFLOW LB/SEC        PT3 PSIA                TT3 DEG.RANKINE      033134
 18.0                          75.2                   901.7                033134
SIMULATED THRUST LBS          FUEL-AIR RATIO MEAS.                         033134
1950.0                        0.0122                                       033134
SIMULATED INLET PRESSURE PO PSIA                                           033134
14.696                                                                     033134
SIMULATED INLET TEMPERATURE TO DEG.RANKINE                                 033134
518.7                                                                      033134
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                        033134
 26.8                                                                      033134
FILTER AREA .385 SI                                                        033134
CLEAN CK SMOKE NUMBER 0                                                    033134
SMOKE NUMBER      VOL.-LITERS      FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH     033134
        4.5               3.0          0.50     11.311             76.0    033134
        2.3               4.0          0.50     11.311             76.0    033134
        8.8               7.0          0.50     11.311             76.0    033134
       12.9              11.0          0.50     11.311             76.0    033134
GASEOUS EMISSIONS                                                          033134
                  FID        NDIR       NDIR       CHEMI      CHEMI        033134
                  UHC        CO         CO2        NO         NOX          033134
RANGE              1          2          2          2          2           033134
INSTR GAS TEMP    150.       61.        61.        64.        64.          033134
RAW VALUE MV       18.6      445.0      568.5      296.8      409.2        033134
GAS CONCEN PPM(C)   17.0      190.5     24683.4      30.5       42.0       033134
GAS CONCEN PCT    0.0017     0.0191     2.4683     0.0030     0.0042       033134
EMISSION INDEX     0.68       15.5      3154.        4.1        5.6        033134
FUEL-AIR RATIO    0.0120                                                   033134
```

```
COMBUSTOR RIG TEST                                                         073144
DATE                         DATA POINT           TEST CELL                073144
 3/25/77                     073144               1                        073144
INSTRUMENT OPERATOR                               TEST OPERATOR            073144
TREMPLEY                                          EHARDT                   073144
ENGINE MANUFACTURER          MODEL                SERIAL NUMBER            073144
LYCOMING                     ALF-502              LF04                     073144
FUEL IDENT.                  FUEL FLOW PPH        MANIFOLD FUEL TEMP FAH   073144
JET-A HC RATIO 0.152          787.                226.3                    073144
ORIFICE AIRFLOW LB/SEC       PT3 PSIA             TT3 DEG.RANKINE          073144
 17.8                         75.1                901.7                    073144
SIMULATED THRUST LBS         FUEL-AIR RATIO MEAS.                          073144
1950.0                       0.0123                                        073144
SIMULATED INLET PRESSURE PO PSIA                                           073144
14.696                                                                     073144
SIMULATED INLET TEMPERATURE TO DEG.RANKINE                                 073144
518.7                                                                      073144
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                        073144
 51.1                                                                      073144
FILTER AREA .385 SI                                                        073144
CLEAN CK SMOKE NUMBER 0                                                    073144
SMOKE NUMBER        VOL.-LITERS     FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH    073144
       4.5                3.0          0.50    11.365              76.0    073144
       2.3                4.0          0.50    11.365              76.0    073144
      10.9                7.0          0.50    11.365              76.0    073144
      14.9               11.0          0.50    11.365              76.0    073144
GASEOUS EMISSIONS                                                          073144
                    FID        NDIR       NDIR        CHEMI       CHEMI    073144
                    UHC        CO         CO2         NO          NOX      073144
RANGE                1          2          2           2           2       073144
INSTR GAS TEMP      150.       60.        60.         64.         64.      073144
RAW VALUE MV         20.6      452.8      574.7       273.1       383.3    073144
GAS CONCEN PPM(C)      19.8       194.2     24990.2       28.0        39.4 073144
GAS CONCEN PCT      0.0020     0.0194     2.4990      0.0028      0.0039   073144
EMISSION INDEX       0.79       15.6      3154.          3.7         5.2   073144
FUEL-AIR RATIO      0.0122                                                 073144
```

```
COMBUSTOR RIG TEST                                                                      1C3144
DATE                          CATA POINT              TEST CELL                         1C3144
 3/25/77                      103144                  1                                 103144
INSTRUMENT OPERATCR                                   TEST OPERATOR                     103144
TREMBLEY                                              EFARCT                            1C3144
ENGINE MANUFACTURER           MODEL                   SERIAL NUMBER                     103144
LYCOMING                      ALF-5C2                 LF04                              1C3144
FUEL IDENT.                   FUEL FLCW PPH           MANIFCLD FUEL TEMP FAH            103144
JET-A HC RATIO C.152           783.                   226.4                             1C3144
ORIFICE AIRFLOW LB/SEC        FT3 PSIA                TT3 CEG.RANKINE                   1C3144
 17.7                          75.1                   9CC.8                             103144
SIMULATED THRUST LBS          FUEL-AIR RATIC MEAS.                                      1C3144
1950.0                        0.0123                                                    103144
SIMULATED INLET PRESSURE PC PSIA                                                        1C3144
14.696                                                                                  103144
SIMULATED INLET TEMPEFATURE TC CEG.RANKINE                                              1C3144
518.7                                                                                   103144
SPECIFIC HUMIDITY GRAINS/LB CRY AIR                                                     1C3144
 69.9                                                                                   1C3144
FILTER AREA .3E5 SI                                                                     1C3144
CLEAN CK SMCKE NUMBER 0                                                                 1C3144
SMOKE NUMBER         VCL.-LITERS      FLCW-CFM PRESS.-FSIA   TEMP. DEG.FAH              1C3144
         4.5                3.0           C.50      11.321             78.0             103144
         6.7                4.0           C.50      11.321             78.C             103144
         8.8                7.C           0.50      11.321             78.0             103144
        10.9               11.C           C.50      11.321             78.C             103144
GASEOUS EMISSICNS                                                                       1C3144
                     FID        NDIR       NDIR       CHEMI      CHEMI                  103144
                     UHC        CO         CO2        NC         NCX                    1C3144
RANGE                 1          2          2          2          2                     103144
INSTR GAS TEMP       15C.       58.        58.        64.        64.                    103144
RAW VALUE MV         28.5       478.5      574.5      257.2      366.4                  1C3144
GAS CONCEN PPM(C)      27.6       206.9      24983.2       26.4       37.6              103144
GAS CONCEN PCT       C.CC28     C.0207     2.4983     0.CC26     C.C038                 103144
EMISSION INDEX        1.09       16.6      3151.         3.5        5.C                 1C3144
FUEL-AIR RATIO       C.C122                                                             103144
```

```
COMBUSTOR RIG TEST                                                            163144
DATE                             DATA POINT            TEST CELL              163144
 3/25/77                         163144                1                      163144
INSTRUMENT OPERATOR                                    TEST OPERATOR          163144
TREMBLEY                                               EHARDT                 163144
ENGINE MANUFACTURER              MODEL                 SERIAL NUMBER          163144
LYCOMING                         ALF-502               LF04                   163144
FUEL IDENT.                      FUEL FLOW PPH         MANIFOLD FUEL TEMP FAH 163144
JET-A HC RATIO 0.152              843.                 225.7                  163144
ORIFICE AIRFLOW LB/SEC           PT3 PSIA              TT3 DEG.RANKINE        163144
 19.5                             80.9                 901.8                  163144
SIMULATED THRUST LBS             FUEL-AIR RATIO MEAS.                         163144
1950.0                           0.0120                                       163144
SIMULATED INLET PRESSURE PO PSIA                                              163144
15.855                                                                        163144
SIMULATED INLET TEMPERATURE TO DEG.RANKINE                                    163144
518.7                                                                         163144
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                           163144
 51.6                                                                         163144
FILTER AREA .385 ST                                                           163144
CLEAN CK SMOKE NUMBER 0                                                       163144
SMOKE NUMBER        VOL.-LITERS     FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH       163144
        8.8                 3.0         0.50     11.351              80.0     163144
        6.7                 4.0         0.50     11.351              80.0     163144
        6.7                 7.0         0.50     11.351              80.0     163144
       14.9                11.0         0.50     11.351              80.0     163144
GASEOUS EMISSIONS                                                             163144
                    FID        NDIR        NDIR       CHEMI      CHEMI        163144
                    UHC         CO          CO2        NO         NOX         163144
RANGE                1          2           2          2          2           163144
INSTR GAS TEMP      150.       62.         62.        65.        64.          163144
RAW VALUE MV         19.8      445.5       563.6      271.8      385.3        163144
GAS CONCEN PPM(C)     21.3      192.8       24444.8       28.0       35.7     163144
GAS CONCEN PCT      0.0021     0.0193      2.4445     0.0028     0.0040       163144
EMISSION INDEX       0.86       15.8       3153.         3.8        5.4       163144
FUEL-AIR RATIO      0.0119                                                    163144
```

```
COMBUSTOR RIG TEST                                                          043134
DATE                           DATA POINT            TEST CELL              043134
 3/25/77                       043134                1                      043134
INSTRUMENT OPERATOR                                  TEST OPERATOR          043134
TREMBLEY                                             EHARDT                 043134
ENGINE MANUFACTURER            MODEL                 SERIAL NUMBER          043134
LYCOMING                       ALF-502               LF04                   043134
FUEL IDENT.                    FUEL FLOW PPH         MANIFOLD FUEL TEMP FAH 043134
JET-A HC RATIO 0.152            815.                 225.2                  043134
ORIFICE AIRFLOW LB/SEC         PT3 PSIA              TT3 DEG.RANKINE        043134
 17.5                           75.0                 945.8                  043134
SIMULATED THRUST LBS           FUEL-AIR RATIO MEAS.                         043134
1950.0                         0.0129                                       043134
SIMULATED INLET PRESSURE PO PSIA                                            043134
14.696                                                                      043134
SIMULATED INLET TEMPERATURE TO DEG.RANKINE                                  043134
544.7                                                                       043134
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                         043134
 25.4                                                                       043134
FILTER AREA .385 SI                                                         043134
CLEAN CK SMOKE NUMBER 0                                                     043134
SMOKE NUMBER        VOL.-LITERS     FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH     043134
         4.5                3.0         0.50   11.346             79.0      043134
         2.3                4.0         0.50   11.346             79.0      043134
         8.8                7.0         0.50   11.346             79.0      043134
        14.9               11.0         0.48   11.297             80.0      043134
 GASEOUS EMISSIONS                                                          043134
                   FID        NDIR        NDIR        CHEMI       CHEMI     043134
                   UHC         CO         CO2          NO          NOX      043134
 RANGE              1          2           2           2           2        043134
 INSTR GAS TEMP    150.       57.         57.         64.         64.       043134
 RAW VALUE MV        9.8     384.4       595.8       262.4       472.5      043134
 GAS CONCEN PPM(C)   10.5      164.1      26067.7       37.2        48.5    043134
 GAS CONCEN PCT    0.0011    0.0164      2.6068      0.0037      0.0048     043134
 EMISSION INDEX     0.40      12.7       3159.          4.7         6.1     043134
 FUEL-AIR RATIO    0.0127                                                   043134
```

```
COMBUSTOR RIG TEST                                                              C83134
DATE                        DATA POINT                TEST CELL                 C83134
 3/28/77                    C83134                    1                         C83134
INSTRUMENT OPERATOR                                   TEST OPERATOR             C83134
TREMBLEY                                              EHARDT                    C83134
ENGINE MANUFACTURER         MODEL                     SERIAL NUMBER             C83134
LYCOMING                    ALF-5C2                   LF04                      C83134
FUEL IDENT.                 FUEL FLOW PPH             MANIFOLD FUEL TEMP FAH    C83134
JET-A HC RATIO 0.158         816.                     229.0                     C83134
ORIFICE AIRFLOW LB/SEC      PT3 PSIA                  TT3 DEG.RANKINE           C83134
 18.0                        75.1                     942.7                     C83134
SIMULATED THRUST LBS        FUEL-AIR RATIO MEAS.                                C83134
1950.0                      0.0126                                              C83134
SIMULATED INLET PRESSURE PO PSIA                                                C83134
14.696                                                                          C83134
SIMULATED INLET TEMPERATURE TO DEG.RANKINE                                      C83134
544.7                                                                           C83134
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                             C83134
 51.4                                                                           C83134
FILTER AREA .385 SI                                                             C83134
CLEAN CK SMOKE NUMBER 0                                                         C83134
SMOKE NUMBER        VOL.-LITERS      FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH        C83134
        2.3                 3.0         0.50     11.439            75.0         C83134
        2.3                 4.0         0.50     11.439            75.0         C83134
        6.7                 7.0         0.50     11.390            75.0         C83134
       10.9                11.0         0.49     11.390            75.0         C83134
GASEOUS EMISSIONS                                                               C83134
                    FID         NDIR        NDIR        CHEMI       CHEMI       C83134
                    UHC          CO          CO2         NO          NOX        C83134
RANGE                1           2           2           2           2          C83134
INSTR GAS TEMP      151.        64.         64.         64.         64.         C83134
RAW VALUE MV         21.9       439.9       587.3       304.7       419.4       C83134
GAS CONCEN PPM(C)     18.3       185.5       25306.3       30.7        42.5     C83134
GAS CONCEN PCT      0.0018      0.0186      2.5306      0.0031      0.0043      C83134
EMISSION INDEX       0.72        14.7       3150.          4.0         5.5      C83134
FUEL-AIR RATIO      0.0124                                                      C83134
```

```
COMBUSTOR RIG TEST                                                 113144
DATE                    DATA POINT          TEST CELL              113144
 3/28/77                113144              1                      113144
INSTRUMENT OPERATOR                         TEST OPERATOR          113144
TREMBLEY                                    EHARDT                 113144
ENGINE MANUFACTURER     MODEL               SERIAL NUMBER          113144
LYCOMING                ALF-502             LF04                   113144
FUEL IDENT.             FUEL FLOW PPH       MANIFOLD FUEL TEMP FAH 113144
JET-A HC RATIO 0.158     808.               228.9                  113144
ORIFICE AIRFLOW LB/SEC  PT3 PSIA            TT3 DEG.RANKINE        113144
 17.6                    75.4               942.1                  113144
SIMULATED THRUST LBS    FUEL-AIR RATIO MEAS.                       113144
1950.0                  0.0127                                     113144
SIMULATED INLET PRESSURE PO PSIA                                   113144
14.696                                                             113144
SIMULATED INLET TEMPERATURE TO DEG.RANKINE                         113144
544.7                                                              113144
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                113144
103.2                                                              113144
FILTER AREA .385 SI                                                113144
CLEAN CK SMOKE NUMBER 0                                            113144
SMOKE NUMBER     VOL.-LITERS    FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH 113144
       2.3              3.0        0.50    11.383           76.0   113144
       4.5              4.0        0.50    11.383           76.0   113144
       8.8              7.0        0.50    11.383           76.0   113144
      10.9             11.0        0.50    11.530           76.0   113144
GASEOUS EMISSIONS                                                  113144
                  FID      NDIR      NDIR      CHEMI     CHEMI     113144
                  UHC      CO        CO2       NO        NOX       113144
RANGE              1        2         2         2         2        113144
INSTR GAS TEMP    152.     58.       58.       64.       64.       113144
RAW VALUE MV       32.3    477.3     594.1     265.7     367.3     113144
GAS CONCEN PPM(C)   26.7    203.5    25639.3      25.6      37.1   113144
GAS CONCEN PCT    0.0027   0.0204    2.5639    0.0026    0.0037    113144
EMISSION INDEX     1.03     15.9     3147.        3.3       4.7    113144
FUEL-AIR RATIO    0.0125                                           113144
```

```
COMBUSTOR RIG TEST                                                               133154
DATE                             DATA POINT          TEST CELL                   133154
 3/28/77                         133154              1                           133154
INSTRUMENT OPERATOR                                  TEST OPERATOR               133154
TREMBLEY                                             EHARDT                      133154
ENGINE MANUFACTURER              MODEL               SERIAL NUMBER               133154
LYCOMING                         ALF-502             LFC4                        133154
FUEL IDENT.                      FUEL FLOW PPH       MANIFOLD FUEL TEMP FAH      133154
JET-A HC RATIO 0.158              812.               226.4                       133154
ORIFICE AIRFLOW LB/SEC           PT3 PSIA            TT3 DEG.RANKINE             133154
 17.0                             75.1               944.0                       133154
SIMULATED THRUST LBS             FUEL-AIR RATIO MEAS.                            133154
1950.0                           0.0132                                          133154
SIMULATED INLET PRESSURE PO PSIA                                                 133154
14.696                                                                           133154
SIMULATED INLET TEMPERATURE TO DEG.RANKINE                                       133154
544.7                                                                            133154
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                              133154
175.0                                                                            133154
FILTER AREA .385 SI                                                              133154
CLEAN CK SMOKE NUMBER 0                                                          133154
SMOKE NUMBER        VOL.-LITERS      FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH         133154
        4.5                  3.0          0.50    11.333            74.0         133154
        4.5                  4.0          0.50    11.333            73.0         133154
        6.7                  7.0          0.50    11.358            74.0         133154
        6.7                 11.0          0.50    11.284            75.0         133154
GASEOUS EMISSIONS                                                                133154
                   FID        NDIR       NDIR       CHEMI      CHEMI             133154
                   UHC        CO         CO2        NO         NOX               133154
RANGE               1          2          2          2          2                133154
INSTR GAS TEMP     151.       52.        52.        64.        64.               133154
RAW VALUE MV        44.4      458.5      602.6      229.1      327.0             133154
GAS CONCEN PPM(C)    37.4      217.5     26291.5       22.4       32.3           133154
GAS CONCEN PCT     0.0037     0.0218     2.6291     0.0022     0.0032            133154
EMISSION INDEX      1.41       16.5      3135.         2.8        4.0            133154
FUEL-AIR RATIO     0.0129                                                        133154
```

```
COMBUSTOR RIG TEST
DATE                       CATA POINT          TEST CELL                   104134
 2/30/77                   104134              1                           104134
INSTRUMENT OPERATOR                                                        104134
                                               TEST CPERATCR               104134
TREMBLEY                                       EFARCT                      104134
ENGINE MANUFACTURER        MODEL               SERIAL NUMBER               104134
LYCOMING                   ALF-5C2             LF04                        1C4134
FUEL IDENT.                FUEL FLCW PPH       MANIFCLD FUEL TEMP FAH      1C4134
JET-A HC RATIO C.160       1116.               224.6                       104134
ORIFICE AIRFLCW LB/SEC     FT3 PSIA            TT3 DEG.RANKINE             1C4134
 21.6                       56.5               964.1                       104134
SIMULATED THRUST LBS       FUEL-AIR RATIC MEAS.                            1C4134
2900.0                     0.0144                                          104134
STIMULATED INLET PRESSURE PO PSIA                                          1C4134
14.696                                                                     1C4134
SIMULATED INLET TEMPERATURE TC DEG.RANKINE                                 1C4134
518.7                                                                      104134
SPECIFIC HUMIDITY GRAINS/LB CRY AIR                                        1C4134
 70.4                                                                      1C4134
FILTER AREA .385 SI                                                        104134
CLEAN CK SMCKE NUMBER 0                                                    104134
SMOKE NUMBER      VCL.-LITERS    FLCW-CFM PRESS.-PSIA  TEMP. DEG.FAH       1C4134
        2.3               3.0        C.50   11.354              74.0       104134
       10.9               4.0        C.50   11.379              74.C       1C4134
       14.9               7.C        0.50   11.354              74.0       1C4134
       27.5              11.C        C.50   11.379              74.0       104134
GASEOUS EMISSICNS                                                          104134
                  FIC       NDIR      NDIR       CHEMI      CHEMI          1C4134
                  UFC       CO        CO2        NO         NOX            104134
RANGE              1         2         2          2          2             104134
INSTR GAS TEMP    138.      59.       59.        64.        64.            1C4134
RAW VALUE MV        5.0    242.0     665.4      454.0      525.1           104134
GAS CONCEN PPM(C)   3.5    106.0   29507.1        46.1        53.8         1C4134
GAS CONCEN PCT    C.CC03    C.01C6    2.95C7     0.CC46     0.0054         104134
EMISSION INDEX    C.12        7.2   3148.          5.1        6.C          104134
FUEL-AIR RATIO    C.C144                                                   1C4134
```

```
COMBUSTOR RIG TEST                                                          223154
DATE                        DATA POINT          TEST CELL                   223154
 3/28/77                    223154              1                           223154
INSTRUMENT OPERATOR                             TEST OPERATOR               223154
TREMBLEY                                        EHARDT                      223154
ENGINE MANUFACTURER         MODEL               SERIAL NUMBER               223154
LYCOMING                    ALF-502             LF04                        223154
FUEL IDENT.                 FUEL FLOW PPH       MANIFOLD FUEL TEMP FAH      223154
JET-A HC RATIO 0.158         723.               224.8                       223154
ORIFICE AIRFLOW LB/SEC      PT3 PSIA            TT3 DEG.RANKINE             223154
 14.3                        65.5               579.3                       223154
SIMULATED THRUST LBS        FUEL-AIR RATIO MEAS.                            223154
1950.0                      0.0141                                          223154
SIMULATED INLET PRESSURE P0 PSIA                                            223154
12.761                                                                      223154
SIMULATED INLET TEMPERATURE T0 DEG.RANKINE                                  223154
564.7                                                                       223154
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                         223154
177.5                                                                       223154
FILTER AREA .385 SI                                                         223154
CLEAN CK SMOKE NUMBER 0                                                     223154
SMOKE NUMBER       VOL.-LITERS      FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH     223154
        4.5                3.0          0.50      11.353            72.0    223154
        2.3                4.0          0.50      11.353            72.0    223154
        4.5                7.0          0.50      11.353            72.0    223154
        6.7               11.0          0.50      11.353            72.0    223154
GASEOUS EMISSIONS                                                           223154
                   FID         NDIR        NDIR        CHEMI      CHEMI     223154
                   UHC         CO          CO2         NO         NOX       223154
RANGE              1           2           2           2          2         223154
INSTR GAS TEMP     151.        59.         59.         64.        63.       223154
RAW VALUE MV        30.9       465.3       651.0       250.3      355.6     223154
GAS CONCEN PPM(C)    26.6       198.8       28414.5        25.4       36.2  223154
GAS CONCEN PCT     0.0027      0.0199      2.8414      0.0025     0.0036    223154
EMISSION INDEX      0.93        14.0       3140.          2.9        4.2    223154
FUEL-AIR RATIO     0.0139                                                   223154
```

```
COMBUSTOR RIG TEST
DATE                               DATA POINT                                    C93134
 3/28/77                           C93134                TEST CELL               C93134
INSTRUMENT OPERATOR                                      1                       C93134
TREMBLEY                                                 TEST OPERATOR           C93134
ENGINE MANUFACTURER                                      EFAFDT                  C93134
LYCOMING                           MODEL                 SERIAL NUMBER           C93134
FUEL IDENT.                        ALF-502               LF04                    C93134
JET-A HC RATIO 0.158               FUEL FLOW PPH         MANIFOLD FUEL TEMP FAH  C93134
ORIFICE AIRFLOW LB/SEC              836.                 224.9                   C93134
 17.3                              PT3 PSIA              TT3 DEG.RANKINE         C93134
SIMULATED THRUST LBS                75.3                 980.8                   C93134
1950.0                             FUEL-AIR RATIO MEAS.                          C93134
STIMULATED INLET PRESSURE PO PSIA  0.0134                                        C93134
14.696                                                                           C93134
SIMULATED INLET TEMPERATURE TO DEG.RANKINE                                       C93134
564.7                                                                            C93134
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                              C93134
 57.0                                                                            C93134
FILTER AREA .385 SI                                                              C93134
CLEAN CK SMOKE NUMBER 0                                                          C93134
SMOKE NUMBER          VOL.-LITERS     FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH        C93134
      4.5                 3.0            0.50      11.338              75.0      C93134
      2.3                 4.0            0.49      11.314              73.0      C93134
      8.8                 7.0            0.50      11.363              73.0      C93134
     12.9                11.0            0.50      11.363              73.0      C93134
GASEOUS EMISSIONS                                                                C93134
                      FID       NDIR       NDIR       CHEMI      CHEMI           C93134
                      UHC       CO         CO2        NO         NOX             C93134
RANGE                  1         2          2          2          2              C93134
INSTR GAS TEMP        151.      46.        46.        63.        63.             C93134
RAW VALUE MV          12.2      352.6      621.7      377.8      488.1           C93134
GAS CONCEN PPM(C)       9.4       150.1      27242.4       37.5       48.7       C93134
GAS CONCEN PCT        0.0009    0.0150     2.7242     0.0037     0.0049          C93134
EMISSION INDEX        0.34      11.0       3147.         4.5        5.9          C93134
FUEL-AIR RATIO        0.0133                                                     C93134
                                                                                 C93134
```

```
COMBUSTOR RIG TEST                                                                   123144
DATE                             DATA POINT             TEST CELL                    123144
 3/28/77                         123144                 1                            123144
INSTRUMENT OPERATOR                                     TEST OPERATOR                123144
TREMBLEY                                                EFARDT                       123144
ENGINE MANUFACTURER              MODEL                  SERIAL NUMBER                123144
LYCOMING                         ALF-502                LF04                         123144
FUEL IDENT.                      FUEL FLOW PPH          MANIFOLD FUEL TEMP FAH       123144
JET-A HC RATIO 0.158              832.                  225.4                        123144
ORIFICE AIRFLOW LB/SEC           PT3 PSIA               TT3 DEG.RANKINE              123144
 17.0                             75.2                  579.8                        123144
SIMULATED THRUST LBS             FUEL-AIR RATIO MEAS.                                123144
1950.0                           0.0136                                              123144
SIMULATED INLET PRESSURE P0 PSIA                                                     123144
14.696                                                                               123144
SIMULATED INLET TEMPERATURE T0 DEG.RANKINE                                           123144
564.7                                                                                123144
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                                  123144
104.8                                                                                123144
FILTER AREA .385 SI                                                                  123144
CLEAN CK SMOKE NUMBER 0                                                              123144
SMOKE NUMBER        VOL.-LITERS     FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH              123144
        4.5                3.0          0.52    11.392             72.0              123144
        4.5                4.0          0.50    11.392             72.0              123144
        6.7                7.0          0.50    11.392             72.0              123144
       12.9               11.0          0.50    11.417             72.0              123144
GASEOUS EMISSIONS                                                                    123144
                    FID        NDIR        NDIR        CHEMI       CHEMI             123144
                    UHC        CO          CO2         NO          NOX               123144
RANGE               1          2           2           2           2                 123144
INSTR GAS TEMP      151.       42.         43.         63.         64.               123144
RAW VALUE MV        15.5       368.4       631.2       325.8       429.3             123144
GAS CONCEN PPM(C)      12.6       156.7       27709.1        32.2        42.7        123144
GAS CONCEN PCT      0.0013     0.0157      2.7709      0.0032      0.0043            123144
EMISSION INDEX      0.45       11.3        3146.          3.8         5.1            123144
FUEL-AIR RATIO      0.0136                                                           123144
```

```
COMBUSTOR RIG TEST                                                                  143154
DATE                                 DATA POINT            TEST CELL                143154
 3/28/77                             143154                1                        143154
INSTRUMENT OPERATOR                                        TEST OPERATOR            143154
TREMBLEY                                                   EHARDT                   143154
ENGINE MANUFACTURER                  MODEL                 SERIAL NUMBER            143154
LYCOMING                             ALF-502               LF04                     143154
FUEL IDENT.                          FUEL FLOW PPH         MANIFOLD FUEL TEMP FAH   143154
JET-A HC RATIO 0.158                  832.                 226.4                    143154
ORIFICE AIRFLOW LB/SEC               PT3 PSIA              TT3 DEG.RANKINE          143154
 16.7                                 75.4                 579.7                    143154
SIMULATED THRUST LBS                 FUEL-AIR RATIO MEAS.                           143154
1950.0                               0.0138                                         143154
SIMULATED INLET PRESSURE PO PSIA                                                    143154
14.696                                                                              143154
SIMULATED INLET TEMPERATURE TO DEG.RANKINE                                          143154
564.7                                                                               143154
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                                 143154
173.6                                                                               143154
FILTER AREA .385 SI                                                                 143154
CLEAN CK SMOKE NUMBER 0                                                             143154
SMOKE NUMBER         VOL.-LITERS       FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH          143154
        4.5                  3.0           0.50    11.397              73.0         143154
        2.3                  4.0           0.50    11.348              73.0         143154
        6.7                  7.0           0.50    11.348              72.0         143154
       10.9                 11.0           0.50    11.373              72.0         143154
GASEOUS EMISSIONS                                                                   143154
                      FID        NDIR        NDIR        CHEMI        CHEMI         143154
                      UHC         CO          CO2         NO           NOX          143154
RANGE                  1          2           2           2            2            143154
INSTR GAS TEMP       151.        67.         67.         63.          64.           143154
RAW VALUE MV          24.9      410.6       637.2       268.6        366.8          143154
GAS CONCEN PPM(C)      20.7       175.0      27999.5          26.4         36.4     143154
GAS CONCEN PCT       0.0021      0.0175      2.8000      0.0026       0.0036        143154
EMISSION INDEX        0.74        12.5       3143.          3.1          4.3        143154
FUEL-AIR RATIO       0.0137                                                         143154
```

```
COMBUSTOR RIG TEST                                                          183154
DATE                       DATA POINT          TEST CELL                    183154
 3/28/77                   183154              1                            183154
INSTRUMENT OPERATOR                            TEST OPERATOR                183154
TREMBLEY                                       EHARDT                       183154
ENGINE MANUFACTURER        MODEL               SERIAL NUMBER                183154
LYCOMING                   ALF-502             LFC4                         183154
FUEL IDENT.                FUEL FLOW PPH       MANIFOLD FUEL TEMP FAH       183154
JET-A HC RATIO 0.158        893.               223.9                        183154
ORIFICE AIRFLOW LB/SEC     PT3 PSIA            TT3 DEG.RANKINE              183154
 18.7                       81.0               575.8                        183154
SIMULATED THRUST LBS       FUEL-AIR RATIO MEAS.                             183154
1950.0                     0.0133                                           183154
SIMULATED INLET PRESSURE PO PSIA                                            183154
15.855                                                                      183154
SIMULATED INLET TEMPERATURE TO DEG.RANKINE                                  183154
564.7                                                                       183154
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                         183154
173.4                                                                       183154
FILTER AREA .385 SI                                                         183154
CLEAN CK SMOKE NUMBER 0                                                     183154
SMOKE NUMBER       VOL.-LITERS      FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH     183154
        2.3               3.0           0.50     11.354             74.0    183154
        2.3               4.0           0.50     11.591             74.0    183154
        6.7               7.0           0.50     11.354             74.0    183154
       10.9              11.0           0.50     11.591             74.0    183154
GASEOUS EMISSIONS                                                           183154
                   FID        NDIR       NDIR        CHEMI      CHEMI       183154
                   UHC         CO         CO2         NO         NOX        183154
RANGE               1          2          2           2          2          183154
INSTR GAS TEMP     152.       58.        58.         64.        64.         183154
RAW VALUE MV        32.6      455.4      624.9       248.3      360.6       183154
GAS CONCEN PPM(C)    27.8      194.0      27138.1       25.2       36.8     183154
GAS CONCEN PCT     0.0028     0.0194     2.7138      0.0025     0.0037      183154
EMISSION INDEX      1.02       14.3      3139.          3.1        4.4      183154
FUEL-AIR RATIO     0.0133                                                   183154
```

```
COMBUSTOR RIG TEST                                                                      114144
DATE                         DATA POINT          TEST CELL                              114144
 2/30/77                     114144              1                                      114144
INSTRUMENT OPERATOR                              TEST OPERATOR                          114144
TREMBLEY                                         EHARDT                                 114144
ENGINE MANUFACTURER          MODEL               SERIAL NUMBER                          114144
LYCOMING                     ALF-502             LF04                                   114144
FUEL IDENT.                  FUEL FLOW PPH       MANIFOLD FUEL TEMP FAH                 114144
JET-A HC RATIO 0.160         1116.               223.4                                  114144
ORIFICE AIRFLOW LB/SEC       PT3 PSIA            TT3 DEG.RANKINE                        114144
 20.5                         96.6               1012.                                  114144
SIMULATED THRUST LBS         FUEL-AIR RATIO MEAS.                                       114144
2900.0                       0.0151                                                     114144
SIMULATED INLET PRESSURE PO PSIA                                                        114144
14.696                                                                                  114144
SIMULATED INLET TEMPERATURE TO DEG.RANKINE                                              114144
544.7                                                                                   114144
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                                     114144
106.4                                                                                   114144
GASEOUS EMISSIONS                                                                       114144
                  FID        NDIR       NDIR        CHEMI       CHEMI                   114144
                  UHC         CO         CO2         NO          NOX                    114144
RANGE              1          1          2           2           2                      114144
INSTR GAS TEMP    138.       60.        60.         64.         64.                     114144
RAW VALUE MV        2.5      768.4      717.6       496.5       555.5                   114144
GAS CONCEN PPM(C)     1.6      68.2      32232.0        50.1        56.1                114144
GAS CONCEN PCT    0.0002     0.0068     3.2232      0.0050      0.0056                  114144
EMISSION INDEX     0.05        4.2      3153.          5.1         5.7                  114144
FUEL-AIR RATIO    0.0158                                                                114144
```

APPENDIX C

ENGINE DATA

```
ENGINE TEST CATA                                                          221101
CATE                          DATA POINT           TEST CELL              221101
C8/11/76                      221101               13                     221101
INSTRUMENT OPERATOR                                TEST OPERATOR          221101
ERHARDT                                            TREMBLEY               221101
ENGINE MANUFACTURER           MODEL                SERIAL NUMBER          221101
LYCCMING                      ALF-502              LF02                   221101
FUEL IDENT.                   FUEL FLOW PPH        MANIFOLD FUEL TEMP FAH 221101
JET-A HC RATIO 0.161           411.                166.6                  221101
BELLMOUTH AIR FLOW LB/SEC     CORE AIRFLOW LB/SEC  FUEL-AIR RATIO MEAS.   221101
 68.1                          9.7                 0.0118                 221101
PT3 PSIA                      TT3 DEG. RANKINE                            221101
 34.4                          720.5                                      221101
PT9 PSIA                      TT9 DEG RANKINE      EPR                    221101
14.985                        1255.6                2.32                  221101
NET THRUST LBS                N1 RPM               N2 RPM                 221101
 412.0                        11104.               1903.                  221101
ACTUAL INLET PRESSURE PO PSIA                                             221101
14.797                                                                    221101
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                                   221101
537.6                                                                     221101
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                       221101
101.4                                                                     221101
FILTER AREA .385 SI                                                       221101
CLEAN CK SMCKE NUMBER 0                                                   221101
SMCKE NUMBER      VOL.-LITERS     FLCW-CFM PRESS.-PSIA  TEMP. DEG.FAH     221101
       2.3                3.0         0.45    11.650              85.0    221101
       2.3                4.0         0.47    11.847              85.0    221101
       2.3                7.0         0.47    11.847              85.0    221101
       2.3               11.0         0.45    11.847              85.0    221101
GASEOUS EMISSICNS                                                         221101
                  FID        NDIR        NDIR       CHEMI     CHEMI       221101
                  UHC         CC          CO2        NO        NCX        221101
RANGE              2          3           2          1         1          221101
INSTR GAS TEMP    153.       55.         55.        62.       62.         221101
RAW VALUE MV      19.0       422.6       513.8      532.7     766.6       221101
GAS CCNCEN PPM(C)  139.2      509.5       22237.0        13.6      19.4   221101
GAS CCNCEN PCT    0.0139     0.0509      2.2237     0.0014    0.0019      221101
EMISSICN INDEX     6.08       44.7       3065.         1.9       2.8      221101
FUEL-AIR RATIO    0.0111                                                  221101
```

```
ENGINE TEST CATA                                                           226701
CATE                           DATA PCINT          TEST CELL               226701
C9/11/76                       2267C1              13                      226701
INSTRUMENT OPERATOR                                TEST CPERATOR           226701
ERHARDT                                            TREMBLEY                226701
ENGINE MANUFACTURER            MODEL               SERIAL NUMBER           226701
LYCOMING                       ALF-502             LF02                    226701
FUEL IDENT.                    FUEL FLCW PPH       MANIFCLC FUEL TEMP FAH  226701
JET-A HC RATIO 0.161           2517.               236.7                   226701
BELLMCUTH AIR FLOW LB/SEC      CORE AIRFLCW LB/SEC FUEL-AIR RATIO MEAS.    226701
232.5                          33.7                0.0208                  226701
PT3 PSIA                       TT3 DEG. RANKINE                            226701
153.4                         1161.2                                       226701
PT9 PSIA                       TT9 DEG RANKINE     EPR                     226701
18.317                         1612.3              10.40                   226701
NET THRUST LBS                 N1 RPM              N2 RPM                  226701
6003.0                         19402.              6210.                   226701
ACTUAL INLET PRESSURE PO PSIA                                              2267C1
14.710                                                                     226701
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                                   2267C1
536.2                                                                      226701
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                        2267C1
 99.5                                                                      226701
FILTER AREA .385 SI                                                        226701
CLEAN CK SMCKE NUMBER 0                                                    226701
SMCKE NUMBER         VOL.-LITERS     FLCW-CFM PRESS.-PSIA   TEMP. DEG.FAH  226701
         24.1                3.0         0.52      13.565            88.0  226701
         22.4                4.0         C.53      13.467            87.0  2267C1
         32.4                7.0         0.53      13.418            89.0  226701
         38.3               11.0         0.52      13.270            89.0  226701
GASEOUS EMISSIONS                                                          2267C1
                     FID       NDIR      NCIR      CHEMI     CHEMI         2267C1
                     UHC        CO       CO2        NO        NOX          226701
RANGE                 1         1         2         3         3            2267C1
INSTR GAS TEMP       153.      52.       52.       61.       61.           226701
RAW VALUE MV           6.5     103.6     922.1     420.6   . 443.3         2267C1
GAS CCNCEN PPM(C)       4.2       7.6     44278.1      107.6     113.4      226701
GAS CONCEN PCT       0.CCC4    C.CCC8    4.4278    0.0108    0.0113        226701
EMISSION INCEX        0.C9       C.3     3154.        8.C       8.4        226701
FUEL-AIR RATIC       C.0218                                                2267C1
```

```
ENGINE TEST DATA                                                                    228601
CATE                            CATA PCINT          TEST CELL                       228601
C8/11/76                        228601              13                              228601
INSTRUMENT OPERATOR                                 TEST OPERATOR                   228601
ERHARCT                                             TREMBLEY                        228601
ENGINE MANUFACTURER             MODEL               SERIAL NUMBER                   228601
LYCOMING                        ALF-502             LF02                            228601
FUEL IDENT.                     FUEL FLCW PPH       MANIFCLD FUEL TEMP FAH          228601
JET-A HC RATIO 0.161            2234.               252.2                           228601
BELLMCUTH AIR FLOW LB/SEC       CORE AIRFLOW LB/SEC FUEL-AIR RATIO MEAS.            228601
220.7                           31.9                0.0195                          228601
PT3 PSIA                        TT3 DEG. RANKINE                                    228601
142.8                          1138.5                                               228601
PT9 PSIA                        TT9 DEG RANKINE     EPR                             228601
17.792                          1563.0               9.72                           228601
NET THRUST LBS                  N1 RFM              N2 RPM                          228601
5402.0                          19078.              6472.                           228601
ACTUAL INLET PRESSURE PO PSIA                                                       228601
14.701                                                                              228601
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                                            228601
536.6                                                                               228601
SPECIFIC HUMIDITY GRAINS/LB CRY AIR                                                 228601
 92.8                                                                               228601
FILTER AREA .385 SI                                                                 228601
CLEAN CK SMCKE NUMBER 0                                                             228601
SMOKE NUMBER          VOL.-LITERS     FLCW-CFM PRESS.-PSIA  TEMP. DEG.FAH           228601
         18.7                 3.0         0.53      13.314           88.0           228601
         22.4                 4.0         0.53      13.314           87.0           228601
         32.4                 7.0         0.52      13.314           88.0           228601
         39.7                11.0         0.50      13.265           88.0           228601
GASEOUS EMISSIONS                                                                   228601
                   FID        NDIR        NCIR      CHEMI       CHEMI               228601
                   UHC         CO          CO2       NO          NOX                228601
RANGE               1          1           2         3           3                  228601
INSTR GAS TEMP     153.        53.         53.       62.         62.                228601
RAW VALUE MV         6.1        83.6       867.0     361.1       385.4              228601
GAS CCNCEN PPM(C)      1.8         6.8     41824.6       91.1        97.3           228601
GAS CCNCEN PCT     0.0002      0.CCC7      4.1825    C.CC91      0.C097             228601
EMISSICN INDEX       0.04        0.3       3154.        7.2         7.7             228601
FUEL-AIR RATIC     C.02C6                                                           228601
```

```
ENGINE TEST DATA                                                          227501
DATE                          DATA POINT          TEST CELL               227501
08/11/76                      227501              13                      227501
INSTRUMENT OPERATOR                               TEST OPERATOR           227501
ERHARDT                                           TREMBLEY                227501
ENGINE MANUFACTURER           MODEL               SERIAL NUMBER           227501
LYCOMING                      ALF-502             LF02                    227501
FUEL IDENT.                   FUEL FLOW PPH       MANIFOLD FUEL TEMP FAH  227501
JET-A HC RATIO 0.161          1262.               239.7                   227501
BELLMOUTH AIR FLOW LB/SEC     CORE AIRFLOW LB/SEC FUEL-AIR RATIO MEAS.    227501
171.8                         24.6                0.0143                  227501
PT3 PSIA                      TT3 DEG. RANKINE                            227501
100.5                        1015.9                                       227501
PT9 PSIA                      TT9 DEG RANKINE     EPR                     227501
16.212                        1354.6               6.82                   227501
NET THRUST LBS                N1 RPM              N2 RPM                  227501
3082.0                        17276.              4706.                   227501
ACTUAL INLET PRESSURE PO PSIA                                             227501
14.735                                                                    227501
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                                  227501
536.2                                                                     227501
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                       227501
 94.2                                                                     227501
FILTER AREA .385 SI                                                       227501
CLEAN CK SMOKE NUMBER 0                                                   227501
SMOKE NUMBER        VOL.-LITERS     FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH   227501
        14.9                3.0         0.53     11.939            88.0   227501
        12.9                4.0         0.55     11.841            88.0   227501
        22.4                7.0         0.53     11.841            88.0   227501
        29.2               11.0         0.52     11.890            88.0   227501
GASEOUS EMISSIONS                                                         227501
                    FID       NDIR      NDIR      CHEMI     CHEMI         227501
                    UHC       CO        CO2       NO        NOX           227501
RANGE                1         1         2         2         2            227501
INSTR GAS TEMP      154.      53.       53.       62.       62.           227501
RAW VALUE MV          7.4     334.7     642.4     495.1     536.7         227501
GAS CONCEN PPM(C)     2.7      31.0      29259.1      53.1      57.6      227501
GAS CONCEN PCT      0.0003    0.0031    2.9259    0.0053    0.0058        227501
EMISSION INDEX       0.09       2.1     3151.         6.0       6.5       227501
FUEL-AIR RATIO      0.0143                                                227501
```

```
ENGINE TEST CATA                                                                     224401
CATE                       DATA POINT            TEST CELL                           224401
C8/11/76                   224401                13                                  224401
INSTRUMENT OPERATOR                              TEST CPERATOR                       224401
ERHARCT                                          TREMBLEY                            224401
ENGINE MANUFACTURER        MODEL                 SERIAL NUMBER                       224401
LYCOMING                   ALF-502               LF02                                224401
FUEL IDENT.                FUEL FLCW PPH         MANIFOLD FUEL TEMP FAH              224401
JET-A HC RATIO 0.161       1074.                 231.4                               224401
BELLMCUTH AIR FLOW LB/SEC  CORE AIRFLCW LB/SEC   FUEL-AIR RATIO MEAS.                224401
159.1                      22.4                  0.0133                              224401
PT3 PSIA                   TT3 DEG. RANKINE                                          224401
 90.2                       981.0                                                    224401
PT9 PSIA                   TT9 DEG RANKINE       EPR                                 224401
15.943                     1305.5                 6.12                               224401
NET THRUST LBS             N1 RPM                N2 RPM                              224401
2568.C                     16742.                4319.                               224401
ACTUAL INLET PRESSURE PO PSIA                                                        224401
14.745                                                                               224401
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                                             224401
535.5                                                                                224401
SPECIFIC HUMIDITY GRAINS/LB CRY AIR                                                  224401
106.1                                                                                224401
FILTER AREA .385 SI                                                                  224401
CLEAN CK SMCKE NUMBER 0                                                              224401
SMOKE NUMBER        VOL.-LITERS      FLCW-CFM PRESS.-PSIA  TEMP. DEG.FAH             224401
       10.9                 3.0          0.52     12.233            86.0             224401
       12.9                 4.0          0.52     12.283            85.0             224401
       22.4                 7.0          0.50     12.283            86.0             224401
       29.2                11.0          0.52     12.283            85.0             224401
GASEOUS EMISSIONS                                                                    224401
                    FID         NDIR        NDIR        CHEMI       CHEMI            224401
                    UHC         CC          CO2         NO          NOX              224401
RANGE               1           1           2           2           2                224401
INSTR GAS TEMP      153.        53.         53.         62.         62.              224401
RAW VALUE MV          7.4       560.0       558.3       405.9       460.1            224401
GAS CCNCEN PPM(C)       2.4        55.2        26992.9       43.9        49.8        224401
GAS CCNCEN PCT      C.C002      0.CC55      2.6993      0.0044      0.C050           224401
EMISSICN INDEX        0.09         4.1      3148.          5.4         6.1           224401
FUEL-AIR RATIO      C.C132                                                           224401
```

```
ENGINE TEST CATA                                                           223301
CATE                          CATA PCINT           TEST CELL               223301
C8/11/76                      2233C1               13                      223301
INSTRUMENT CPERATOR                                TEST OPERATOR           223301
ERHARDT                                            TREMBLEY                223301
ENGINE MANUFACTURER           MODEL                SERIAL NUMBER           223301
LYCCMING                      ALF-502              LF02                    223301
FUEL IDENT.                   FUEL FLCW PPH        MANIFCLD FUEL TEMP FAH  223301
JET-A HC RATIO 0.161           743.                221.2                   223301
BELLMCUTH AIR FLCW LB/SEC     CORE AIRFLCW LB/SEC  FUEL-AIR RATIO MEAS.    223301
128.4                         18.3                 0.0113                  223301
PT3 PSIA                      TT3 DEG. RANKINE                             223301
 70.2                          891.8                                       223301
FT9 PSIA                      TT9 DEG RANKINE      EPR                     223301
15.5C8                        12C9.1                4.76                   223301
NET THRLST LBS                N1 FFM               N2 RPM                  223301
1658.0                        15410.               3526.                   223301
ACTUAL INLET PRESSURE PO PSIA                                              223301
14.768                                                                     223301
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                                   223301
536.1                                                                      223301
SPECIFIC HUMIDITY GRAINS/LB CRY AIR                                        223301
104.1                                                                      223301
FILTER AREA .385 SI                                                        223301
CLEAN CK SMCKE NUMBER 0                                                    223301
SMOKE NUMEER        VOL.-LITERS     FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH    223301
         6.7                3.0          0.52     11.989           85.0    223301
         6.7                4.0          0.53     11.989           84.0    223301
        10.9                7.0          0.53     11.989           84.0    223301
        14.9               11.0          0.52     11.989           84.0    223301
GASEOUS EMISSICNS                                                          223301
                      FID      NDIR      NDIR      CHEMI     CHEMI         223301
                      UHC       CC        CO2       NO        NOX          223301
RANGE                  1        2         2         2         2            223301
INSTR GAS TEMP       154.      53.       53.       62.       62.           223301
RAW VALLE MV          21.9     314.3     509.0     267.3     334.6         223301
GAS CCNCEN PPM(C)     13.1     132.3   22448.8      29.0      36.2         223301
GAS CCNCEN FCT       C.0013    0.C132    2.2449    0.0029    0.C036        223301
EMISSION INDEX         0.58     11.8     3134.        4.2       5.3        223301
FUEL-AIF RATIC       0.0110                                                223301
```

```
ENGINE TEST DATA
DATE                                                                          222201
08/11/76                        DATA POINT          TEST CELL                 222201
INSTRUMENT OPERATOR             222201              13                        222201
ERHARDT                                             TEST OPERATOR             222201
ENGINE MANUFACTURER                                 TREMBLEY                  222201
LYCOMING                        MODEL               SERIAL NUMBER             222201
FUEL IDENT.                     ALF-502             LF02                      222201
JET-A HC RATIO 0.161            FUEL FLOW PPH       MANIFOLD FUEL TEMP FAH    222201
BELLMOUTH AIR FLOW LB/SEC        457.               188.6                     222201
 80.7                           CORE AIRFLOW LB/SEC FUEL-AIR RATIO MEAS.      222201
PT3 PSIA                        11.6                0.0109                    222201
 40.8                           TT3 DEG. RANKINE                              222201
PT9 PSIA                         762.9                                        222201
15.057                          TT5 DEG RANKINE      EPR                      222201
NET THRUST LBS                  1231.6               2.76                     222201
 616.0                          N1 RPM              N2 RPM                    222201
ACTUAL INLET PRESSURE PO PSIA   12398.              2218.                     222201
14.769                                                                        222201
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                                      222201
536.4                                                                         222201
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                           222201
104.1                                                                         222201
FILTER AREA .385 SI                                                           222201
CLEAN CK SMOKE NUMBER 0                                                       222201
SMOKE NUMBER         VOL.-LITERS    FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH       222201
        0.0                  3.0        0.50    11.940                        222201
        2.3                  4.0        0.52    11.940               85.0     222201
        2.3                  7.0        0.50    11.891               84.0     222201
        4.5                 11.0        0.52    11.842               84.0     222201
GASEOUS EMISSIONS                                                    85.0     222201
                     FID         NDIR        NDIR         CHEMI               222201
                     UHC         CO          CO2          NO        CHEMI     222201
RANGE                1           2           2            1         NOX       222201
INSTR GAS TEMP       153.        52.         52.          62.       1         222201
RAW VALUE MV          90.5       719.3       509.5        580.8     62.       222201
GAS CONCEN PPM(C)      64.0       355.0       22473.4        14.9   896.2     222201
GAS CONCEN PCT       0.0064      0.0355      2.2473       0.0015       22.7   222201
EMISSION INDEX        2.79        31.1       3097.           2.1    0.0023    222201
FUEL-AIR RATIO       0.0112                                            3.3    222201
                                                                              222201
```

```
ENGINE TEST DATA                                                           221111
DATE                          DATA POINT           TEST CELL               221111
08/11/76                      221111               13                      221111
INSTRUMENT OPERATOR                                TEST OPERATOR           221111
ERHARDT                                            TREMBLEY                221111
ENGINE MANUFACTURER           MODEL                SERIAL NUMBER           221111
LYCOMING                      ALF-502              LF02                    221111
FUEL IDENT.                   FUEL FLOW PPH        MANIFOLD FUEL TEMP FAH  221111
JET-A HC RATIO 0.161           380.                172.0                   221111
BELLMOUTH AIR FLOW LB/SEC     CORE AIRFLOW LB/SEC  FUEL-AIR RATIO MEAS.    221111
 67.6                          9.5                 0.0111                  221111
PT3 PSIA                      TT3 DEG. RANKINE                             221111
 33.7                          714.6                                       221111
PT9 PSIA                      TT9 DEG RANKINE      EPR                     221111
14.979                        1252.9                2.28                   221111
NET THRUST LBS                N1 RPM               N2 RPM                  221111
 413.0                        10960.               1854.                   221111
ACTUAL INLET PRESSURE PC PSIA                                              221111
14.780                                                                     221111
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                                   221111
535.6                                                                      221111
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                        221111
105.9                                                                      221111
FILTER AREA .385 SI                                                        221111
CLEAN CK SMOKE NUMBER 0                                                    221111
SMOKE NUMBER        VOL.-LITERS      FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH   221111
         2.3                 3.0         0.50      11.893           85.0   221111
         2.3                 4.0         0.50      11.893           84.0   221111
         2.3                 7.0         0.50      11.844           85.0   221111
         2.3                11.0         0.49      11.844           85.0   221111
GASEOUS EMISSIONS                                                          221111
                     FID      NDIR       NDIR      CHEMI     CHEMI         221111
                    UHC        CO         CO2      NO         NOX          221111
RANGE                1         2          2          1         1           221111
INSTR GAS TEMP      154.      52.        52.       62.       62.           221111
RAW VALUE MV        143.1     888.3      515.5     465.0     793.5         221111
GAS CONCEN PPM(C)    103.0     449.1     22775.5       12.0      20.2      221111
GAS CONCEN PCT      0.0103    0.0449     2.2776    0.0012    0.0020        221111
EMISSION INDEX       4.41      38.7      3080.        1.7       2.9        221111
FUEL-AIR RATIO      0.0114                                                 221111
```

```
ENGINE TEST DATA                                                                     231102
DATE                        DATA POINT           TEST CELL                           231102
08/11/76                    231102               13                                  231102
INSTRUMENT OPERATOR                              TEST OPERATOR                       231102
ERHARDT                                          TREMBLEY                            231102
ENGINE MANUFACTURER         MODEL                SERIAL NUMBER                       231102
LYCOMING                    ALF-502              LF02                                231102
FUEL IDENT.                 FUEL FLOW PPH        MANIFOLD FUEL TEMP FAH              231102
JET-A HC RATIO 0.161         392.                164.5                               231102
BELLMOUTH AIR FLOW LB/SEC   CORE AIRFLOW LB/SEC  FUEL-AIR RATIO MEAS.                231102
 67.5                        9.6                 0.0114                              231102
PT3 PSIA                    TT3 DEG. RANKINE                                         231102
 34.1                        712.7                                                   231102
PT9 PSIA                    TT9 DEG RANKINE      EPR                                 231102
14.992                      1246.4                2.30                               231102
NET THRUST LBS              N1 RPM               N2 RPM                              231102
 422.0                      11006.               1880.                               231102
ACTUAL INLET PRESSURE PO PSIA                                                        231102
14.795                                                                               231102
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                                             231102
532.6                                                                                231102
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                                  231102
115.8                                                                                231102
FILTER AREA .385 SI                                                                  231102
CLEAN CK SMOKE NUMBER 0                                                              231102
SMOKE NUMBER         VOL.-LITERS     FLOW-CFM PRESS.-PSIA   TEMP. DEG.FAH            231102
          2.3                3.0         0.50     11.850             82.0            231102
          2.3                4.0         0.49     11.800             82.0            231102
          2.3                7.0         0.48     11.800             82.0            231102
          2.3               11.0         0.49     11.800             83.0            231102
GASEOUS EMISSIONS                                                                    231102
                     FID        NDIR        NDIR        CHEMI       CHEMI            231102
                     UHC         CO          CO2         NO          NOX             231102
RANGE                 1          2           2           1           1               231102
INSTR GAS TEMP       153.       56.         56.         62.         62.              231102
RAW VALUE MV         154.7      897.0       512.5       457.2       781.9            231102
GAS CONCEN PPM(C)     112.2      456.3       22805.5        11.7         19.8        231102
GAS CONCEN PCT       0.0112     0.0456      2.2805      0.0012      0.0020           231102
EMISSION INDEX        4.80       39.2       3078.          1.6          2.8          231102
FUEL-AIR RATIO       0.0114                                                          231102
```

```
ENGINE TEST DATA                                                  236702
DATE                   DATA POINT          TEST CELL              236702
08/11/76               236702              13                     236702
INSTRUMENT OPERATOR                        TEST OPERATOR          236702
ERHARDT                                    TREMBLEY               236702
ENGINE MANUFACTURER    MODEL               SERIAL NUMBER          236702
LYCOMING               ALF-502             LF02                   236702
FUEL IDENT.            FUEL FLOW PPH       MANIFOLD FUEL TEMP FAH 236702
JET-A HC RATIO 0.161   2568.               231.1                  236702
BELLMOUTH AIR FLOW LB/SEC  CORE AIRFLOW LB/SEC FUEL-AIR RATIO MEAS. 236702
233.0                  34.1                0.0210                 236702
PT3 PSIA               TT3 DEG. RANKINE                           236702
155.4                 1154.2                                      236702
PT9 PSIA               TT9 DEG RANKINE     EPR                    236702
18.473                 1611.4              10.60                  236702
NET THRUST LBS         N1 RPM              N2 RPM                 236702
6133.0                 19370.              6253.                  236702
ACTUAL INLET PRESSURE PO PSIA                                     236702
14.709                                                            236702
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                          236702
530.4                                                             236702
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                               236702
116.5                                                             236702
FILTER AREA .385 SI                                               236702
CLEAN CK SMOKE NUMBER 0                                           236702
SMOKE NUMBER     VOL.-LITERS     FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH  236702
        18.7             3.0         0.53    13.324           84.0  236702
        27.6             4.0         0.53    13.374           83.0  236702
        33.9             7.0         0.53    13.422           83.0  236702
        39.7            11.0         0.52    13.373           84.0  236702
GASEOUS EMISSIONS                                                 236702
                 FID         NDIR       NDIR       CHEMI      CHEMI     236702
                 UHC         CO         CO2        NO         NOX       236702
RANGE            1           1          2          3          3         236702
INSTR GAS TEMP   153.        54.        54.        62.        62.       236702
RAW VALUE MV       5.1       116.1      914.1      400.3      426.7     236702
GAS CONCEN PPM(C)   1.5        9.9     45105.3      102.6      109.5    236702
GAS CONCEN PCT   0.0002      0.0010     4.5105     0.0103     0.0109    236702
EMISSION INDEX     0.03        0.4      3154.         7.5        8.0    236702
FUEL-AIR RATIO   0.0222                                           236702
```

```
ENGINE TEST DATA                                                      238602
DATE                         DATA POINT          TEST CELL            238602
08/11/76                     238602              13                   238602
INSTRUMENT OPERATOR                              TEST OPERATOR        238602
ERHARDT                                          TREMBLEY             238602
ENGINE MANUFACTURER          MODEL               SERIAL NUMBER        238602
LYCOMING                     ALF-502             LF02                 238602
FUEL IDENT.                  FUEL FLOW PPH       MANIFOLD FUEL TEMP FAH 238602
JET-A HC RATIO 0.161         2288.               239.4                238602
BELLMOUTH AIR FLOW LB/SEC    CORE AIRFLOW LB/SEC FUEL-AIR RATIO MEAS. 238602
225.1                        32.7                0.0195               238602
PT3 PSIA                     TT3 DEG. RANKINE                         238602
145.3                       1131.3                                    238602
PT9 PSIA                     TT9 DEG RANKINE     EPR                  238602
17.929                       1559.2               9.89                238602
NET THRUST LBS               N1 RPM              N2 RPM               238602
5580.0                       19076.              6014.                238602
ACTUAL INLET PRESSURE PO PSIA                                         238602
14.721                                                                238602
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                              238602
530.8                                                                 238602
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                   238602
116.4                                                                 238602
FILTER AREA .385 SI                                                   238602
CLEAN CK SMOKE NUMBER 0                                               238602
SMOKE NUMBER        VOL.-LITERS     FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH 238602
        22.4                3.0         0.52     13.323          87.0 238602
        24.1                4.0         0.53     13.373          87.0 238602
        33.9                7.0         0.53     13.422          86.0 238602
        42.4               11.0         0.52     13.373          87.0 238602
GASEOUS EMISSIONS                                                     238602
                    FID         NDIR         NDIR        CHEMI      CHEMI    238602
                    UHC         CO           CO2         NO         NOX      238602
RANGE               1           1            2           2          2        238602
INSTR GAS TEMP      153.        53.          53.         62.        62.      238602
RAW VALUE MV          3.7         86.2       866.0       849.4      915.4    238602
GAS CONCEN PPM(C)       0.5          7.3     42074.4        91.8       99.0  238602
GAS CONCEN PCT      0.0001      0.0007       4.2074      0.0092     0.0099   238602
EMISSION INDEX        0.01         0.4       3154.          7.2        7.8   238602
FUEL-AIR RATIO      0.0207
```

```
ENGINE TEST CATA                                                          237502
DATE                     CATA POINT          TEST CELL                    237502
C8/11/76                 2375C2              13                           237502
INSTRUMENT OPERATOR                          TEST OPERATOR                237502
ERHARDT                                      TREMBLEY                     237502
ENGINE MANUFACTURER      MODEL               SERIAL NUMBER                237502
LYCCMING                 ALF-502             LF02                         237502
FUEL IDENT.              FUEL FLOW PPH       MANIFOLC FUEL TEMP FAH       237502
JET-A HC RATIO 0.161     1275.               236.1                        237502
BELLMOUTH AIR FLOW LB/SEC CORE AIRFLOW LB/SEC FUEL-AIR RATIO MEAS.        237502
174.7                    24.8                0.0143                       237502
PT3 PSIA                 TT3 CEG. RANKINE                                 237502
101.9                   1CC9.6                                            237502
FT9 PSIA                 TT9 DEG RANKINE     EPR                          237502
16.251                   1347.6               6.91                        237502
NET THRUST LBS           N1 RPM              N2 RPM                       237502
3168.0                   17248.              4729.                        237502
ACTUAL INLET PRESSURE PO PSIA                                             237502
14.752                                                                    237502
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                                  237502
530.7                                                                     2375C2
SPECIFIC HUMIDITY GRAINS/LB CRY AIR                                       237502
112.6                                                                     237502
FILTER AREA .385 SI                                                       237502
CLEAN CK SMCKE NUMBER 0                                                   237502
SMCKE NUMBER         VOL.-LITERS     FLCW-CFM PRESS.-PSIA  TEMP. DEG.FAH  237502
      12.9                  3.0           0.52    11.799           85.0   237502
      14.9                  4.0           C.53    11.897           85.0   237502
      24.1                  7.0           0.52    11.897           85.0   237502
      30.8                 11.C           0.52    11.848           84.0   237502
GASEOUS EMISSIONS                                                         237502
                   FID       NDIR       NDIR       CHEMI      CHEMI       237502
                   UHC       CO         CO2        NO         NOX         237502
RANGE              1         1          2          2          2           237502
INSTR GAS TEMP     153.      54.        54.        62.        62.         237502
RAW VALUE MV         4.6     341.5      639.7      468.7      514.0       237502
GAS CCNCEN PPM(C)    1.3      31.8      29399.4        50.8       55.8    237502
GAS CCNCEN PCT     0.0001    0.0032     2.9399     0.0051     0.0056      237502
EMISSICN INCEX       0.04      2.2      3151.          5.7        6.2     237502
FUEL-AIR RATIC     0.0144                                                 237502
```

```
ENGINE TEST DATA                                                                   234402
DATE                         DATA POINT            TEST CELL                       234402
08/11/76                     234402                13                              234402
INSTRUMENT OPERATOR                                TEST OPERATOR                   234402
ERHARDT                                            TREMBLEY                        234402
ENGINE MANUFACTURER          MODEL                 SERIAL NUMBER                   234402
LYCOMING                     ALF-502               LF02                            234402
FUEL IDENT.                  FUEL FLOW PPH         MANIFOLD FUEL TEMP FAH          234402
JET-A HC RATIO 0.161         1103.                 230.1                           234402
BELLMOUTH AIR FLOW LB/SEC    CORE AIRFLOW LB/SEC   FUEL-AIR RATIO MEAS.            234402
161.8                        23.0                  0.0133                          234402
PT3 PSIA                     TT3 DEG. RANKINE                                      234402
 92.4                         980.8                                                234402
PT9 PSIA                     TT9 DEG RANKINE       EPR                             234402
16.016                       1299.4                 6.27                           234402
NET THRUST LBS               N1 RPM                N2 RPM                          234402
2705.0                       16798.                4381.                           234402
ACTUAL INLET PRESSURE PO PSIA                                                      234402
14.752                                                                             234402
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                                           234402
530.0                                                                              234402
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                                234402
113.0                                                                              234402
FILTER AREA .385 SI                                                                234402
CLEAN CK SMOKE NUMBER 0                                                            234402
SMOKE NUMBER        VOL.-LITERS      FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH           234402
        10.9                3.0          0.52     11.799            83.0           234402
        14.9                4.0          0.52     11.897            83.0           234402
        20.6                7.0          0.52     11.848            83.0           234402
        29.2               11.0          0.52     11.848            83.0           234402
GASEOUS EMISSIONS                                                                  234402
                    FID        NDIR       NDIR       CHEMI       CHEMI             234402
                    UHC        CO         CO2        NO          NOX               234402
RANGE               1          1          2          2           2                 234402
INSTR GAS TEMP      153.       54.        54.        62.         62.               234402
RAW VALUE MV          5.6      539.5      596.6      402.7       457.5             234402
GAS CONCEN PPM(C)       1.9       53.0     27120.2        43.7        49.6         234402
GAS CONCEN PCT      0.0002     0.0053     2.7120     0.0044      0.0050            234402
EMISSION INDEX      0.07          3.9     3148.          5.3         6.0           234402
FUEL-AIR RATIO      0.0133                                                         234402
```

```
ENGINE TEST DATA                                                                  233302
DATE                          DATA POINT            TEST CELL                     233302
08/11/76                      233302                13                            233302
INSTRUMENT OPERATOR                                 TEST OPERATOR                 233302
ERHARDT                                             TREMBLEY                      233302
ENGINE MANUFACTURER           MODEL                 SERIAL NUMBER                 233302
LYCOMING                      ALF-502               LF02                          233302
FUEL IDENT.                   FUEL FLOW PPH         MANIFOLD FUEL TEMP FAH        233302
JET-A HC RATIO 0.161           774.                 215.6                         233302
BELLMOUTH AIR FLOW LB/SEC     CORE AIRFLOW LB/SEC   FUEL-AIR RATIO MEAS.          233302
131.1                         19.0                  0.0113                        233302
PT3 PSIA                      TT3 DEG. RANKINE                                    233302
 72.5                          911.1                                              233302
PT9 PSIA                      TT9 DEG RANKINE       EPR                           233302
15.549                        1205.4                 4.91                         233302
NET THRUST LBS                N1 RPM                N2 RPM                        233302
1770.0                        15512.                3597.                         233302
ACTUAL INLET PRESSURE PO PSIA                                                     233302
14.760                                                                            233302
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                                          233302
530.0                                                                             233302
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                               233302
112.5                                                                             233302
FILTER AREA .385 SI                                                               233302
CLEAN CK SMOKE NUMBER 0                                                           233302
SMOKE NUMBER       VOL.-LITERS      FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH           233302
         6.7               3.0          0.50     11.845            83.0           233302
         6.7               4.0          0.50     11.845            82.0           233302
        10.9               7.0          0.53     11.796            83.0           233302
        16.8              11.0          0.52     11.845            83.0           233302
GASEOUS EMISSIONS                                                                 233302
                  FID         NDIR        NDIR        CHEMI       CHEMI           233302
                  UHC          CO          CO2          NO         NOX            233302
RANGE              1           2            2           2           2             233302
INSTR GAS TEMP    153.        52.         53.         62.         62.             233302
RAW VALUE MV       18.0       301.6       513.8       262.7       336.4           233302
GAS CONCEN PPM(C)   11.1       126.8      22864.2        28.5        36.5         233302
GAS CONCEN PCT    0.0011      0.0127      2.2864      0.0028      0.0036          233302
EMISSION INDEX     0.48        11.1       3136.          4.1         5.2          233302
FUEL-AIR RATIO    0.0112                                                          233302
```

```
ENGINE TEST DATA                                                      232202
DATE                          DATA POINT           TEST CELL          232202
 08/11/76                     232202               13                 232202
INSTRUMENT OPERATOR                                TEST OPERATOR      232202
ERHARDT                                            TREMBLEY           232202
ENGINE MANUFACTURER           MODEL                SERIAL NUMBER      232202
LYCOMING                      ALF-502              LF02               232202
FUEL IDENT.                   FUEL FLOW PPH        MANIFOLD FUEL TEMP FAH  232202
JET-A HC RATIO 0.161           442.                187.8              232202
BELLMOUTH AIR FLOW LB/SEC     CORE AIRFLOW LB/SEC  FUEL-AIR RATIO MEAS.  232202
 78.7                         11.4                 0.0107             232202
PT3 PSIA                      TT3 DEG. RANKINE                        232202
 39.9                          750.2                                  232202
PT9 PSIA                      TT9 DEG RANKINE      EPR                232202
15.054                        1221.1                2.70              232202
NET THRUST LBS                N1 RPM               N2 RPM             232202
 595.0                        12170.               2178.              232202
ACTUAL INLET PRESSURE PO PSIA                                         232202
14.777                                                                232202
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                              232202
530.0                                                                 232202
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                   232202
114.8                                                                 232202
FILTER AREA .385 SI                                                   232202
CLEAN CK SMOKE NUMBER 0                                               232202
SMOKE NUMBER        VOL.-LITERS   FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH  232202
      2.3                   3.0       0.52    11.795           82.0   232202
      2.3                   4.0       0.52    11.795           83.0   232202
      4.5                   7.0       0.53    11.746           82.0   232202
      4.5                  11.0       0.50    11.819           81.0   232202
GASEOUS EMISSIONS                                                     232202
                    FID       NDIR      NDIR      CHEMI     CHEMI     232202
                    UHC       CO        CO2       NO        NOX       232202
RANGE               1         2         2         1         1         232202
INSTR GAS TEMP      153.      52.       52.       62.       62.       232202
RAW VALUE MV        103.8     763.2     506.1     535.5     861.7     232202
GAS CONCEN PPM(C)     74.6     379.5     22477.1      13.9      22.1  232202
GAS CONCEN PCT      0.0075    0.0379    2.2477    0.0014    0.0022    232202
EMISSION INDEX        3.25     33.2     3092.        2.0       3.2    232202
FUEL-AIR RATIO      0.0112                                            232202
```

```
ENGINE TEST CATA                                                                           231112
CATE                          CATA POINT           TEST CELL                               231112
08/11/76                      231112               13                                      231112
INSTRUMENT CPERATCR                                TEST OPERATOR                           231112
ERHARDT                                            TREMBLEY                                231112
ENGINE MANUFACTURER           MODEL                SERIAL NUMBER                           231112
LYCOMING                      ALF-502              LF02                                    231112
FUEL IDENT.                   FUEL FLCW PPH        MANIFOLC FUEL TEMP FAH                  231112
JET-A HC RATIO 0.161           381.                169.5                                   231112
BELLMCUTH AIR FLCW LB/SEC     CORE AIRFLOW LB/SEC  FUEL-AIR RATIO MEAS.                    231112
 67.2                          9.5                 0.0111                                  231112
PT3 PSIA                      TT3 DEG. RANKINE                                             231112
 33.6                          7C7.2                                                       231112
PT9 PSIA                      TT9 DEG RANKINE      EPR                                     231112
14.982                        1236.9                2.27                                   231112
NET THRLST LBS                N1 RFM               N2 RPM                                  231112
 400.0                        10888.               1860.                                   231112
ACTUAL INLET PRESSURE FC PSIA                                                              231112
14.785                                                                                     231112
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                                                   231112
530.1                                                                                      231112
SPECIFIC HUMICITY GRAINS/LB CRY AIR                                                        231112
113.5                                                                                      231112
FILTER AREA .385 SI                                                                        231112
CLEAN CK SMCKE NUMBER 0                                                                    231112
SMOKE NUMBER      VOL.-LITERS      FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH                     231112
         2.3              3.0          0.50     11.354             83.0                    231112
         2.3              4.0          0.53     11.305             82.0                    231112
         2.3              7.0          0.53     11.354             83.0                    231112
         2.3             11.0          0.52     11.305             83.0                    231112
GASEOUS EMISSICNS                                                                          231112
                  FID        NDIR        NDIR        CHEMI       CHEMI                     231112
                  UHC        CC          CO2         NO          NOX                       231112
RANGE             1          2           2           1           1                         231112
INSTR GAS TEMP    153.       51.         51.         62.         62.                       231112
RAW VALUE MV      155.7      911.0       509.9       436.9       784.0                     231112
GAS CCNCEN PPM(C)  113.0      463.2       22670.6       11.4        20.1                   231112
GAS CCNCEN PCT    0.0113     0.0463      2.2671      0.0011      0.0020                    231112
EMISSICN INCEX     4.86       40.0       3076.          1.6         2.8                    231112
FUEL-AIR RATIO    0.0113                                                                   231112
```

```
ENGINE TEST DATA                                                               241103
DATE                                DATA POINT              TEST CELL          241103
08/12/76                            241103                  13                 241103
INSTRUMENT OPERATOR                                         TEST OPERATOR      241103
ERHARDT                                                     TREMBLEY           241103
ENGINE MANUFACTURER                 MODEL                   SERIAL NUMBER      241103
LYCOMING                            ALF-502                 LF02               241103
FUEL IDENT.                         FUEL FLOW PPH           MANIFOLD FUEL TEMP FAH  241103
JET-A HC RATIO 0.161                 380.                   183.2              241103
BELLMOUTH AIR FLOW LB/SEC           CORE AIRFLOW LB/SEC FUEL-AIR RATIO MEAS.   241103
 66.9                                9.5                    0.0111             241103
PT3 PSIA                            TT3 DEG. RANKINE                           241103
 33.6                                718.2                                     241103
PT9 PSIA                            TT9 DEG RANKINE         EPR                241103
14.909                              1261.9                   2.28              241103
NET THRUST LBS                      N1 RPM                  N2 RPM             241103
 399.0                              10994.                  1861.              241103
ACTUAL INLET PRESSURE PO PSIA                                                  241103
14.708                                                                         241103
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                                       241103
538.2                                                                          241103
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                            241103
107.2                                                                          241103
FILTER AREA .385 SI                                                            241103
CLEAN CK SMOKE NUMBER 0                                                        241103
SMOKE NUMBER        VOL.-LITERS      FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH       241103
      0.0                  3.0           0.52      11.081             87.0     241103
      0.0                  4.0           0.52      11.081             87.0     241103
      2.3                  7.0           0.52      11.130             87.0     241103
      2.3                 11.0           0.53      11.130             87.0     241103
GASEOUS EMISSIONS                                                              241103
                   FID         NDIR        NDIR        CHEMI       CHEMI       241103
                   UHC          CO          CO2         NO          NOX        241103
RANGE               1          2           2           1           1           241103
INSTR GAS TEMP     153.        54.         54.         62.         62.         241103
RAW VALUE MV       188.6       969.3       518.6       457.5       783.1       241103
GAS CONCEN PPM(C)   139.3       506.4       23039.2         11.6        19.9   241103
GAS CONCEN PCT     0.0139      0.0506      2.3039      0.0012      0.0020      241103
EMISSION INDEX      5.88        42.9       3069.          1.6         2.8      241103
FUEL-AIR RATIO     0.0115                                                      241103
```

```
ENGINE TEST CATA                                                                     246703
CATE                                    DATA POINT          TEST CELL                246703
C8/12/76                                246703              13                       246703
INSTRUMENT CPERATOR                                         TEST OPERATOR            246703
ERHARCT                                                     TREMBLEY                 246703
ENGINE MANUFACTURER                     MODEL               SERIAL NUMBER            246703
LYCCMING                                ALF-502             LF02                     246703
FUEL ICENT.                             FUEL FLOW PPH       MANIFCLD FUEL TEMP FAH   246703
JET-A HC RATIO 0.161                    2464.               230.9                    246703
BELLMCUTH AIR FLOW LB/SEC               CORE AIRFLCW LB/SEC FUEL-AIR RATIO MEAS.     246703
228.1                                   33.2                C.0206                   246703
PT3 PSIA                                TT3 DEG. RANKINE                             246703
151.3                                  1153.C                                        246703
PT9 PSIA                                TT9 DEG RANKINE     EPR                      246703
18.170                                  16C6.5              10.40                    246703
NET THRUST LBS                          N1 RPM              N2 RPM                   246703
5858.0                                  193C6.              6185.                    246703
ACTUAL INLET PRESSURE PO PSIA                                                        246703
14.626                                                                               246703
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                                             246703
535.2                                                                                246703
SPECIFIC HUMIDITY GRAINS/LB CRY AIR                                                  246703
105.2                                                                                246703
FILTER AREA .385 SI                                                                  246703
CLEAN CK SMCKE NUMBER 0                                                              246703
SMCKE NUMBER        VOL.-LITERS     FLCW-CFM PRESS.-PSIA  TEMP. DEG.FAH              246703
        18.7                3.0         0.53      11.227           87.0              246703
        24.1                4.0         C.53      11.227           87.0              246703
        25.9                7.0         0.53      11.227           87.0              246703
        35.4               11.0         C.54      11.276           87.0              246703
GASEOUS EMISSIONS                                                                    246703
                 FIC         NDIR        NCIR        CHEMI       CHEMI               246703
                 UHC         CC          CC2         NC          NOX                 246703
RANGE            1           1           2           3           3                   246703
INSTR GAS TEMP   153.        54.         54.         62.         62.                 246703
RAW VALUE MV       3.1       117.C       9C4.5       392.3       423.8               246703
GAS CCNCEN PPM(C)    0.2         8.4     44701.6       101.6       109.8             246703
GAS CCNCEN PCT   C.0CC0      C.CCC8      4.4702      0.0102      0.0110              246703
EMISSION INDEX     0.0C        C.4       3154.         7.5         8.1               246703
FUEL-AIR RATIO   C.0220                                                              2467C3
```

```
ENGINE TEST DATA
DATE                                                                              248603
08/12/76                        DATA POINT          TEST CELL                     248603
INSTRUMENT OPERATOR             248603              13                            248603
ERHARDT                                             TEST OPERATOR                 248603
ENGINE MANUFACTURER                                 TREMBLEY                      248603
LYCOMING                        MODEL               SERIAL NUMBER                 248603
FUEL IDENT.                     ALF-502             LF02                          248603
JET-A HC RATIO 0.161            FUEL FLOW PPH       MANIFOLD FUEL TEMP FAH        248603
BELLMOUTH AIR FLOW LB/SEC       2208.               245.8                         248603
220.0                           CORE AIRFLOW LB/SEC FUEL-AIR RATIO MEAS.          248603
PT3 PSIA                        31.5                0.0195                        248603
141.2                           TT3 DEG. RANKINE                                  248603
PT9 PSIA                       1131.0                                             248603
17.706                          TT9 DEG RANKINE     EPR                           248603
NET THRUST LBS                  1561.1               9.66                         248603
5314.0                          N1 RPM              N2 RPM                        248603
ACTUAL INLET PRESSURE PO PSIA   19014.              5928.                         248603
14.628                                                                            248603
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                                          248603
535.5                                                                             248603
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                               248603
104.0                                                                             248603
FILTER AREA .385 SI                                                               248603
CLEAN CK SMOKE NUMBER 0                                                           248603
SMOKE NUMBER          VOL.-LITERS     FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH         248603
      18.7                    3.0         0.52     11.226             87.0        248603
      20.6                    4.0         0.53     11.226             87.0        248603
      29.2                    7.0         0.53     11.275             87.0        248603
      36.9                   11.0         0.53     11.226             87.0        248603
GASEOUS EMISSIONS                                                                 248603
                 FID          NDIR        NDIR        CHEMI       CHEMI           248603
                 UHC          CO          CO2         NO          NOX             248603
RANGE            1            1           2           2           2               248603
INSTR GAS TEMP   153.         54.         54.         62.         62.             248603
RAW VALUE MV       2.3        95.8        853.2       826.8       888.1           248603
GAS CONCEN PPM(C)  -0.4          6.6      41467.8        90.9        97.7         248603
GAS CONCEN PCT   -.0000       0.0007      4.1468      0.0091      0.0098          248603
EMISSION INDEX   -0.01        0.3         3154.          7.2         7.8          248603
FUEL-AIR RATIO   0.0204                                                           248603
                                                                                  248603
```

```
ENGINE TEST DATA                                                        247503
DATE                        DATA POINT           TEST CELL              247503
08/12/76                    247503               13                     247503
INSTRUMENT OPERATOR                              TEST OPERATOR          247503
ERHARDT                                          TREMBLEY               247503
ENGINE MANUFACTURER         MODEL                SERIAL NUMBER          247503
LYCOMING                    ALF-502              LF02                   247503
FUEL IDENT.                 FUEL FLOW PPH        MANIFOLD FUEL TEMP FAH 247503
JET-A HC RATIO 0.161        1255.                244.2                  247503
BELLMOUTH AIR FLOW LB/SEC   CORE AIRFLOW LB/SEC  FUEL-AIR RATIO MEAS.   247503
170.2                       24.4                 0.0143                 247503
PT3 PSIA                    TT3 DEG. RANKINE                            247503
100.1                      1015.0                                       247503
PT9 PSIA                    TT9 DEG RANKINE      EPR                    247503
16.137                      1357.9                6.83                  247503
NET THRUST LBS              N1 RPM               N2 RPM                 247503
3086.0                      17284.               4715.                  247503
ACTUAL INLET PRESSURE PO PSIA                                           247503
14.668                                                                  247503
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                                247503
536.0                                                                   247503
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                     247503
105.6                                                                   247503
FILTER AREA .385 SI                                                     247503
CLEAN CK SMOKE NUMBER 0                                                 247503
SMOKE NUMBER         VOL.-LITERS     FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH 247503
        12.9                3.0          0.52     11.078          86.0  247503
        12.9                4.0          0.52     11.078          86.0  247503
        16.8                7.0          0.53     11.127          86.0  247503
        25.9               11.0          0.53     11.127          86.0  247503
GASEOUS EMISSIONS                                                       247503
                     FID        NDIR       NDIR       CHEMI      CHEMI  247503
                     UHC         CO         CO2        NO         NOX   247503
RANGE                1          1          2          2          2      247503
INSTR GAS TEMP       153.       53.        53.        62.        62.    247503
RAW VALUE MV           3.1      352.8      638.8      468.1      517.3  247503
GAS CONCEN PPM(C)      0.2       31.5      29377.0      51.4       56.8 247503
GAS CONCEN PCT       0.0000     0.0031     2.9377     0.0051     0.0057 247503
EMISSION INDEX         0.01       2.1      3151.         5.8        6.4 247503
FUEL-AIR RATIO       0.0144                                             247503
```

```
ENGINE TEST DATA                                                                 244403
DATE                           DATA POINT           TEST CELL                    244403
08/12/76                       244403               13                           244403
INSTRUMENT OPERATOR                                 TEST OPERATOR                244403
ERHARDT                                             TREMBLEY                     244403
ENGINE MANUFACTURER            MODEL                SERIAL NUMBER                244403
LYCOMING                       ALF-502              LF02                         244403
FUEL IDENT.                    FUEL FLOW PPH        MANIFOLD FUEL TEMP FAH       244403
JET-A HC RATIO 0.161           1060.                235.2                        244403
BELLMOUTH AIR FLOW LB/SEC      CORE AIRFLOW LB/SEC  FUEL-AIR RATIO MEAS.         244403
155.5                          22.5                 0.0131                       244403
PT3 PSIA                       TT3 DEG. RANKINE                                  244403
 89.7                          982.6                                             244403
PT9 PSIA                       TT9 DEG RANKINE      EPR                          244403
15.885                         1305.6                6.12                        244403
NET THRUST LBS                 N1 RPM               N2 RPM                       244403
2557.0                         16760.               4331.                        244403
ACTUAL  INLET PRESSURE PO PSIA                                                   244403
14.670                                                                           244403
ACTUAL  INLET TEMPERATURE TO DEG. RANKINE                                        244403
535.9                                                                            244403
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                              244403
106.0                                                                            244403
FILTER AREA .385 SI                                                              244403
CLEAN CK SMOKE NUMBER 0                                                          244403
SMOKE NUMBER       VOL.-LITERS       FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH         244403
       10.9                3.0           0.52    11.179             86.0         244403
       10.9                4.0           0.53    11.228             86.0         244403
       16.8                7.0           0.53    11.228             86.0         244403
       24.1               11.0           0.54    11.228             86.0         244403
GASEOUS EMISSIONS                                                                244403
                   FID        NDIR        NDIR        CHEMI       CHEMI          244403
                   UHC         CO         CO2          NO          NOX           244403
RANGE               1          1           2           2           2             244403
INSTR GAS TEMP     154.       53.         53.         62.         62.            244403
RAW VALUE MV         3.9      569.7       591.7       397.9       454.4          244403
GAS CONCEN PPM(C)     0.8        54.6     26891.5        43.6        49.8        244403
GAS CONCEN PCT     0.0001     0.0055      2.6892      0.0044      0.0050         244403
EMISSION INDEX       0.03        4.1      3148.          5.3         6.1         244403
FUEL-AIR RATIO     0.0131                                                        244403
```

```
ENGINE TEST CATA                                                                          243303
CATE                              DATA PCINT              TEST CELL                       243303
C8/12/76                          243303                  13                              243303
INSTRUMENT CFERATOR                                       TEST OPERATOR                   243303
ERHARDT                                                   TREMBLEY                        243303
ENGINE MANUFACTURER               MODEL                   SERIAL NUMBER                   243303
LYCCMING                          ALF-502                 LF02                            243303
FUEL IDENT.                       FUEL FLOW PPH           MANIFOLC FUEL TEMP FAH          243303
JET-A HC RATIO C.161               753.                   218.4                           243303
BELLMCUTH AIR FLCW LB/SEC         CORE AIRFLCW LB/SEC     FUEL-AIR RATIO MEAS.            243303
129.7                             18.7                    0.0112                          243303
PT3 PSIA                          TT3 DEG. RANKINE                                        243303
 71.0                              914.0                                                  243303
PT9 PSIA                          TT9 DEG RANKINE         EPR                             243303
15.447                            1212.5                   4.84                           243303
NET THRUST LBS                    N1 RPM                  N2 RPM                          243303
1707.0                            15490.                  3569.                           243303
ACTUAL INLET PRESSURE FC PSIA                                                             243303
14.686                                                                                    243303
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                                                  243303
534.7                                                                                     243303
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                                       243303
110.8                                                                                     243303
FILTER AREA .385 SI                                                                       243303
CLEAN CK SMCKE NUMBER 0                                                                   243303
SMOKE NUMBER        VCL.-LITERS      FLCW-CFM PRESS.-PSIA   TEMP. DEG.FAH                 243303
         6.7                 3.0            0.52     11.080                85.0           243303
         6.7                 4.0            0.53     11.179                85.0           243303
        10.9                 7.0            0.53     11.179                85.0           243303
        14.9                11.0            0.53     11.129                85.0           243303
GASEOUS EMISSICNS                                                                         243303
                     FID          NDIR        NDIR         CHEMI        CHEMI             243303
                     LHC           CO          CO2          NO           NOX              243303
RANGE                 1            2            2           2            2                243303
INSTR GAS TEMP      153.          53.          53.         62.          62.               243303
RAW VALUE MV         18.7         313.2        508.7       256.2        333.8             243303
GAS CCNCEN PPM(C)      12.9         130.1       22738.0          28.0         36.5        243303
GAS CCNCEN PCT      0.0013        0.0130       2.2738      0.0028       0.0036            243303
EMISSION INDEX        0.56          11.4        3135.         4.0          5.3            243303
FUEL-AIR RATIO      0.0111                                                                243303
```

```
ENGINE TEST DATA
DATE                                                                          242203
08/12/76                        DATA POINT              TEST CELL             242203
INSTRUMENT OPERATOR             242203                  13                    242203
ERHARDT                                                 TEST OPERATOR         242203
ENGINE MANUFACTURER                                     TREMBLEY              242203
LYCOMING                        MODEL                   SERIAL NUMBER         242203
FUEL IDENT.                     ALF-502                 LF02                  242203
JET-A HC RATIO 0.161            FUEL FLOW PPH           MANIFOLD FUEL TEMP FAH 242203
BELLMOUTH AIR FLOW LB/SEC        453.                   190.7                 242203
 81.0                           CORE AIRFLOW LB/SEC FUEL-AIR RATIO MEAS.      242203
PT3 PSIA                        11.7                    0.0108                242203
 41.0                           TT3 DEG. RANKINE                              242203
PT9 PSIA                         764.4                                        242203
14.991                          TT9 DEG RANKINE         EPR                   242203
NET THRUST LBS                  1228.3                   2.79                 242203
 631.0                          N1 RPM                  N2 RPM                242203
ACTUAL INLET PRESSURE PO PSIA   12458.                  2225.                 242203
14.704                                                                        242203
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                                      242203
534.9                                                                         242203
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                           242203
111.4                                                                         242203
FILTER AREA .385 SI                                                           242203
CLEAN CK SMOKE NUMBER 0                                                       242203
SMOKE NUMBER        VOL.-LITERS      FLOW-CFM  PRESS.-PSIA  TEMP. DEG.FAH     242203
      0.0                   3.0          0.52       11.079           85.0     242203
      0.0                   4.0          0.52       11.128           85.0     242203
      4.5                   7.0          0.52       11.079           85.0     242203
      2.3                  11.0          0.50       11.079           85.0     242203
GASEOUS EMISSIONS                                                             242203
                    FID        NDIR        NDIR        CHEMI       CHEMI      242203
                    UHC        CO          CO2         NO          NOX        242203
RANGE                1          2           2           1           1         242203
INSTR GAS TEMP      153.       53.         53.         62.         62.        242203
RAW VALUE MV        87.8       720.5       504.2       544.8       888.0      242203
GAS CONCEN PPM(C)     64.6       353.7       22509.6       14.0        22.7   242203
GAS CONCEN PCT      0.0065     0.0354      2.2510      0.0014      0.0023     242203
EMISSION INDEX      2.82       31.0        3097.         2.0         3.3      242203
FUEL-AIR RATIO      0.0112                                                    242203
```

```
ENGINE TEST DATA                                                                 241113
DATE                              DATA POINT          TEST CELL                  241113
08/12/76                          241113              13                         241113
INSTRUMENT OPERATOR                                   TEST OPERATOR              241113
ERHARDT                                               TREMBLEY                   241113
ENGINE MANUFACTURER               MODEL               SERIAL NUMBER              241113
LYCOMING                          ALF-502             LF02                       241113
FUEL IDENT.                       FUEL FLOW PPH       MANIFOLD FUEL TEMP FAH     241113
JET-A HC RATIO 0.161               373.               175.5                      241113
BELLMOUTH AIR FLOW LB/SEC         CORE AIRFLOW LB/SEC FUEL-AIR RATIO MEAS.       241113
 64.5                              9.2                0.0113                     241113
PT3 PSIA                          TT3 DEG. RANKINE                               241113
 32.5                              707.8                                         241113
PT9 PSIA                          TT9 DEG RANKINE     EPR                        241113
14.890                            1261.3               2.21                      241113
NET THRUST LBS                    N1 RPM              N2 RPM                     241113
 389.0                            10728.              1784.                      241113
ACTUAL INLET PRESSURE PO PSIA                                                    241113
14.702                                                                           241113
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                                         241113
535.4                                                                            241113
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                              241113
106.8                                                                            241113
FILTER AREA .385 SI                                                              241113
CLEAN CK SMOKE NUMBER 0                                                          241113
SMOKE NUMBER       VOL.-LITERS       FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH         241113
        0.0                3.0          0.52      11.075             86.0        241113
        0.0                4.0          0.52      11.075             86.0        241113
        0.0                7.0          0.52      11.075             86.0        241113
        2.3               11.0          0.52      11.075             86.0        241113
GASEOUS EMISSIONS                                                                241113
                   FID         NDIR         NDIR         CHEMI      CHEMI        241113
                   UHC          CO          CO2          NO         NOX          241113
RANGE               1           2            2           1          1            241113
INSTR GAS TEMP     153.        52.          52.          62.        62.          241113
RAW VALUE MV       149.3       919.4        515.3        436.8      738.4        241113
GAS CONCEN PPM(C)   110.7       466.5        23073.6       11.3       20.2       241113
GAS CONCEN PCT     0.0111      0.0466       2.3074       0.0011     0.0020       241113
EMISSION INDEX      4.68        39.6        3078.          1.6        2.8        241113
FUEL-AIR RATIO     0.0115                                                        241113
```

```
ENGINE TEST CATA                                                       251104
CATE                          CATA PCINT          TEST CELL            251104
C8/13/76                      251104              13                   251104
INSTRUMENT OPERATCR                               TEST CPERATOR        251104
ERHARDT                                           TREMBLEY             251104
ENGINE MANUFACTURER           MCDEL               SERIAL NUMBER        251104
LYCCMING                      ALF-502             LF02                 251104
FUEL IDENT.                   FUEL FLCW PPH       MANIFCLC FUEL TEMP FAH 251104
JET-A HC RATIO 0.161           362.               175.4                251104
BELLMCUTH AIR FLOW LB/SEC     CORE AIRFLOW LB/SEC FUEL-AIR RATIO MEAS. 251104
 66.6                          9.6                0.0105               251104
FT3 PSIA                      TT3 CEG. RANKINE                         251104
 33.8                          725.3                                   251104
PT9 PSIA                      TT9 CEG RANKINE     EPR                  251104
14.819                        1211.8               2.31                251104
NET THRLST LBS                N1 RPM              N2 RPM               251104
 397.0                        112C8.              1866.                251104
ACTUAL INLET PRESSURE PO PSIA                                          251104
14.621                                                                 251104
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                               251104
539.9                                                                  251104
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                    251104
122.7                                                                  251104
FILTER AREA .385 SI                                                    251104
CLEAN CK SMCKE NUMBER 0                                                251104
SMOKE NUMBER      VOL.-LITERS   FLCW-CFM PRESS.-PSIA  TEMP. DEG.FAH    251104
     0.0                  3.0       0.52    11.039             88.0    251104
     2.3                  4.C       0.52    11.039             88.0    251104
     2.3                  7.0       0.53    11.C89             88.0    251104
     2.3                 11.0       0.52    11.C89             88.0    251104
GASEOUS EMISSIONS                                                      251104
                  FID        NDIR       NDIR       CHEMI      CHEMI    251104
                  UHC        CC         CO2        NO         NOX      251104
RANGE              2         2          2          1          1        251104
INSTR GAS TEMP    153.       55.        55.        62.        62.      251104
RAW VALLE MV       17.3      895.9      468.4      441.9      747.7    251104
GAS CONCEN PPM(C)  128.5      456.5      21159.9      11.2       18.9  251104
GAS CCNCEN PCT    0.C129     C.C456     2.1160     0.0011     0.0019   251104
EMISSION INCEX     5.91       42.1      3070.         1.7        2.9   251104
FUEL-AIR RATIO    C.0106                                               251104
```

```
ENGINE TEST DATA                                                              256704
DATE                     DATA POINT          TEST CELL                        256704
08/13/76                 256704              13                               256704
INSTRUMENT OPERATOR                          TEST OPERATOR                    256704
ERHARDT                                      TREMBLEY                         256704
ENGINE MANUFACTURER      MODEL               SERIAL NUMBER                    256704
LYCOMING                 ALF-502             LF02                             256704
FUEL IDENT.              FUEL FLOW PPH       MANIFOLD FUEL TEMP FAH           256704
JET-A HC RATIO 0.161     2497.               240.9                            256704
BELLMOUTH AIR FLOW LB/SEC CORE AIRFLOW LB/SEC FUEL-AIR RATIO MEAS.            256704
228.3                    32.9                0.0211                           256704
PT3 PSIA                 TT3 DEG. RANKINE                                     256704
151.8                   1163.6                                                256704
PT9 PSIA                 TT9 DEG RANKINE     EPR                              256704
18.101                   1611.7              10.45                            256704
NET THRUST LBS           N1 RPM              N2 RPM                           256704
5783.0                   19462.              6247.                            256704
ACTUAL INLET PRESSURE PO PSIA                                                 256704
14.540                                                                        256704
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                                      256704
537.3                                                                         256704
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                           256704
124.6                                                                         256704
FILTER AREA .385 SI                                                           256704
CLEAN CK SMOKE NUMBER 0                                                       256704
SMOKE NUMBER        VOL.-LITERS     FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH       256704
        14.9                3.0         0.52       11.139             90.0    256704
        18.7                4.0         0.52       11.139             90.0    256704
        30.8                7.0         0.53       11.187             89.0    256704
        36.9               11.0         0.53       11.187             90.0    256704
GASEOUS EMISSIONS                                                             256704
                  FID          NDIR         NDIR         CHEMI       CHEMI    256704
                  UHC          CO           CO2          NO          NOX      256704
RANGE             1            1            2            3           3        256704
INSTR GAS TEMP    153.         54.          54.          62.         62.      256704
RAW VALUE MV        7.2        112.1        883.0        387.6       412.5    256704
GAS CONCEN PPM(C)     3.8          8.5      44563.4        100.0       106.5  256704
GAS CONCEN PCT    0.0004       0.0008       4.4563       0.0100      0.0107   256704
EMISSION INDEX    0.08         0.4          3154.          7.4         7.9    256704
FUEL-AIR RATIO    0.0219                                                      256704
```

```
ENGINE TEST CATA                                                               258604
CATE                          DATA PCINT              TEST CELL                258604
C8/13/76                      258604                  13                       258604
INSTRUMENT CPERATOR                                   TEST OPERATOR            258604
ERHARDT                                               TREMBLEY                 258604
ENGINE MANUFACTURER           MCDEL                   SERIAL NUMBER            258604
LYCCMING                      ALF-502                 LF02                     258604
FUEL IDENT.                   FUEL FLCW PPH           MANIFCLD FUEL TEMP FAH   258604
JET-A HC RATIO 0.161          2213.                   255.2                    258604
BELLMOUTH AIR FLOW LB/SEC     CORE AIRFLOW LB/SEC FUEL-AIR RATIO MEAS.         258604
219.2                         31.3                    0.0197                   258604
PT3 PSIA                      TT3 DEG. RANKINE                                 258604
140.9                        1138.4                                            258604
PT9 PSIA                      TT9 DEG RANKINE         EPR                      258604
17.568                        1562.8                    9.69                   258604
NET THRUST LBS                N1 RPM                  N2 RPM                   258604
5267.0                        19144.                  5979.                    258604
ACTUAL INLET PRESSURE PO PSIA                                                  258604
14.543                                                                         258604
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                                       258604
537.3                                                                          258604
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                            258604
123.8                                                                          258604
FILTER AREA .385 SI                                                            258604
CLEAN CK SMCKE NUMBER 0                                                        258604
SMOKE NUMBER          VOL.-LITERS    FLCW-CFM  PRESS.-PSIA  TEMP. DEG.FAH      258604
        16.8                  3.0        0.52      11.139           89.0       258604
        22.4                  4.0        0.52      11.139           88.0       258604
        29.2                  7.0        0.53      11.089           88.0       258604
        39.7                 11.0        0.53      11.089           88.0       258604
GASEOUS EMISSICNS                                                              258604
                      FID         NDIR        NCIR        CHEMI       CHEMI    258604
                      UHC         CC          CO2         NO          'NOX     258604
RANGE                 1           1           2           2           2        258604
INSTR GAS TEMP        153.        54.         54.         62.         62.      258604
RAW VALUE MV            5.7         89.1      838.1       814.0       878.6    258604
GAS CCNCEN PPM(C)         2.6          6.5     41672.4        89.6        96.8 258604
GAS CONCEN PCT        0.0003      0.0006      4.1672      0.0090      0.0097   258604
EMISSICN INCEX          0.06        0.3       3154.           7.1         7.7  258604
FUEL-AIR RATIO        0.0205                                                   258604
```

```
ENGINE TEST CATA                                                                  257504
CATE                                                                              257504
C8/13/76                      CATA POINT             TEST CELL                    257504
INSTRUMENT CPERATOR           257504                 13                           257504
ERHARDT                                              TEST CPERATOR                257504
ENGINE MANUFACTURER                                  TREMBLEY                     257504
LYCCMING                      MCDEL                  SERIAL NUMBER                257504
FUEL IDENT.                   ALF-502                LF02                         257504
JET-A HC RATIO C.161          FUEL FLOW PPH          MANIFCLD FUEL TEMP FAH       257504
BELLMCUTH AIR FLCW LB/SEC     1260.                  248.6                        257504
171.1                         CORE AIRFLCW LB/SEC    FUEL-AIR RATIO MEAS.         257504
PT3 PSIA                      24.3                   0.0144                       257504
100.2                         TT3 DEG. RANKINE                                    257504
PT9 PSIA                     1021.6                                               257504
16.060                        TT9 DEG RANKINE        EPR                          257504
NET THRUST LBS                1356.8                  6.87                        257504
3C45.C                        N1 RPM                 N2 RPM                       257504
ACTUAL INLET PRESSURE FC PSIA 17382.                 4727.                        257504
14.58C                                                                            257504
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                                          257504
537.7                                                                             257504
SPECIFIC HUMIDITY GRAINS/LB CRY AIR                                               257504
123.C                                                                             257504
FILTER AREA .385 SI                                                               257504
CLEAN CK SMCKE NUMBER 0                                                           257504
SMCKE NUMBER       VOL.-LITERS    FLCW-CFM PRESS.-PSIA  TEMP. DEG.FAH             257504
       10.9               3.0        C.52      11.139                             257504
       12.9               4.0        0.52      11.C89             88.0            257504
       20.6               7.0        0.52      11.C89             88.0            257504
       29.2              11.0        C.53      11.C89             88.0            257504
GASECLS EMISSIONS                                                 88.0            257504
                  FID         NDIR        NDIR       CHEMI      CHEMI             257504
                  UHC         CC          CO2        NO         NOX               257504
RANGE             1           1           2          2          2                 257504
INSTR GAS TEMP    153.        53.         53.        62.        62.               257504
RAW VALUE MV        6.5       344.9       623.9      463.5      513.1             257504
GAS CCNCEN PPM(C)     3.2       31.5      29343.8       50.9       56.4           257504
GAS CCNCEN PCT    C.CCC3      0.0031      2.9344     0.0051     0.0056            257504
EMISSICN INDEX      0.11        2.2       3151.         5.7        6.3            257504
FUEL-AIR RATIO    C.C144                                                          257504
                                                                                  257504
```

```
ENGINE TEST CATA                                                        254404
DATE                     CATA POINT         TEST CELL                   254404
C8/13/76                 254404             13                          254404
INSTRUMENT OPERATCR                         TEST OPERATOR               254404
ERHARDT                                     TREMBLEY                    254404
ENGINE MANUFACTURER      MODEL              SERIAL NUMBER               254404
LYCCMING                 ALF-502            LF02                        254404
FUEL IDENT.              FUEL FLOW PPH      MANIFCLC FUEL TEMP FAH      254404
JET-A HC RATIO 0.161     107C.              236.3                       254404
BELLMCUTH AIR FLCW LB/SEC  CORE AIRFLCW LB/SEC FUEL-AIR RATIO MEAS.     254404
157.3                    22.7               0.0131                      254404
PT3 PSIA                 TT3 DEG. RANKINE                               254404
 90.6                     989.7                                         254404
PT9 PSIA                 TT9 DEG RANKINE    EPR                         254404
15.812                   13C6.0              6.21                       254404
NET THRUST LBS           N1 RPM             N2 RPM                      254404
2588.C                   16886.             4359.                       254404
ACTUAL  INLET PRESSURE PO PSIA                                          254404
14.589                                                                  254404
ACTUAL  INLET TEMPERATURE TO DEG. RANKINE                               254404
537.0                                                                   254404
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                     254404
123.8                                                                   254404
FILTER AREA .385 SI                                                     254404
CLEAN CK SMCKE NUMBER 0                                                 254404
SMOKE NUMBER      VCL.-LITERS    FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH    254404
      10.9               3.0         0.52     11.142            87.0    254404
      12.9               4.0         0.53     11.142            87.0    254404
      18.7               7.0         0.53     11.142            87.0    254404
      25.9              11.0         0.53     11.191            87.0    254404
GASEOUS EMISSIONS                                                       254404
                  FID         NDIR        NDIR        CHEMI       CHEMI    254404
                  UHC          CO         CO2          NO          NOX     254404
RANGE             1           1           2           2           2        254404
INSTR GAS TEMP    153.        55.         55.         62.         62.      254404
RAW VALUE MV        8.2       55C.4       578.3       392.2       448.3    254404
GAS CCNCEN PPM(C)     3.7        52.9      27002.7        42.9        49.0 254404
GAS CCNCEN PCT    C.CC04      0.CC53      2.7C03      0.0043      0.0049   254404
EMISSION INDEX    0.14          3.9       3148.          5.2         6.0   254404
FUEL-AIR RATIO    C.0132                                                   254404
```

```
ENGINE TEST DATA                                                            253304
DATE                         DATA POINT             TEST CELL               253304
08/13/76                     253304                 13                      253304
INSTRUMENT OPERATOR                                 TEST OPERATOR           253304
ERHARDT                                             TREMBLEY                253304
ENGINE MANUFACTURER          MODEL                  SERIAL NUMBER           253304
LYCOMING                     ALF-502                LF02                    253304
FUEL IDENT.                  FUEL FLOW PPH          MANIFOLD FUEL TEMP FAH  253304
JET-A HC RATIO 0.161          749.                  229.6                   253304
BELLMOUTH AIR FLOW LB/SEC    CORE AIRFLOW LB/SEC FUEL-AIR RATIO MEAS.       253304
128.0                        18.6                   0.0112                  253304
PT3 PSIA                     TT3 DEG. RANKINE                               253304
 70.8                         919.4                                         253304
PT9 PSIA                     TT9 DEG RANKINE        EPR                     253304
15.367                       1208.8                  4.85                   253304
NET THRUST LBS               N1 RPM                 N2 RPM                  253304
1662.0                       15582.                 3562.                   253304
ACTUAL INLET PRESSURE PO PSIA                                               253304
14.605                                                                      253304
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                                    253304
536.9                                                                       253304
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                         253304
122.8                                                                       253304
FILTER AREA .385 SI                                                         253304
CLEAN CK SMOKE NUMBER 0                                                     253304
SMOKE NUMBER       VOL.-LITERS      FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH     253304
        6.7                3.0          0.52     11.096            87.0     253304
        6.7                4.0          0.52     11.096            87.0     253304
       10.9                7.0          0.53     11.096            87.0     253304
       14.9               11.0          0.53     11.096            87.0     253304
GASEOUS EMISSIONS                                                           253304
                   FID         NDIR       NDIR        CHEMI       CHEMI     253304
                   UHC          CO         CO2         NO          NOX      253304
RANGE              1            2          2           2           2        253304
INSTR GAS TEMP     153.         54.        54.         62.         62.      253304
RAW VALUE MV        23.6        311.2      494.3       253.7       328.6    253304
GAS CONCEN PPM(C)    15.3       130.0      22583.7       27.8        36.0   253304
GAS CONCEN PCT     0.0015       0.0130     2.2584      0.0028      0.0036   253304
EMISSION INDEX      0.67        11.5       3134.         4.0          5.2   253304
FUEL-AIR RATIO     0.0111                                                   253304
```

```
ENGINE TEST CATA                                                              252204
CATE                        CATA PCINT             TEST CELL                  252204
08/13/76                    252204                 13                         252204
INSTRUMENT OPERATOR                                TEST OPERATOR              252204
ERHARDT                                            TREMBLEY                   252204
ENGINE MANUFACTURER         MCDEL                  SERIAL NUMBER              252204
LYCCMING                    ALF-502                LF02                       252204
FUEL IDENT.                 FUEL FLOW PPH          MANIFCLC FUEL TEMP FAH     252204
JET-A HC RATIO 0.161         435.                  199.0                      252204
BELLMCUTH AIR FLCW LB/SEC   CORE AIRFLOW LB/SEC    FUEL-AIR RATIO MEAS.       252204
 79.8                       11.7                   0.0103                     252204
PT3 PSIA                    TT3 DEG. RANKINE                                  252204
 41.0                        767.8                                            252204
PT9 PSIA                    TT9 DEG RANKINE        EPR                        252204
14.906                      1201.9                  2.80                      252204
NET THRLST LBS              N1 RPM                 N2 RPM                     252204
 599.0                      12574.                 2234.                      252204
ACTUAL INLET PRESSURE PC PSIA                                                 252204
14.625                                                                        252204
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                                      252204
535.7                                                                         252204
SPECIFIC HUMIDITY GRAINS/LB CRY AIR                                           252204
126.5                                                                         252204
FILTER AREA .385 SI                                                           252204
CLEAN CK SMCKE NUMBER 0                                                       252204
SMOKE NUMBER        VOL.-LITERS     FLOW-CFM  PRESS.-PSIA   TEMP. DEG.FAH     252204
        0.0                 3.0         0.50     11.001              86.0     252204
        2.3                 4.0         0.52     11.050              86.0     252204
        2.3                 7.0         0.50     11.050              86.0     252204
        4.5                11.0         0.52     11.050              85.0     252204
GASEOUS EMISSIONS                                                             252204
                    FID       NDIR      NDIR       CHEMI     CHEMI            252204
                    UHC        CC        CO2        NO        NOX             252204
RANGE                1         2         2          1         1               252204
INSTR GAS TEMP      153.      54.       54.        62.       62.              252204
RAW VALUE MV         92.3     710.5     473.8      517.0     841.3            252204
GAS CCNCEN PPM(C)     67.1      350.7    21524.8       13.4       21.5        252204
GAS CCNCEN PCT      0.0067    0.0351    2.1525     0.0013    0.0022           252204
EMISSICN INCEX        3.06      32.1    3095.          2.0        3.2         252204
FUEL-AIR RATIO      0.0107                                                    252204
```

```
ENGINE TEST DATA                                                      251114
DATE                            DATA POINT        TEST CELL           251114
08/13/76                        251114            13                  251114
INSTRUMENT OPERATOR                               TEST OPERATOR       251114
ERHARDT                                           TREMBLEY            251114
ENGINE MANUFACTURER             MODEL             SERIAL NUMBER       251114
LYCOMING                        ALF-502           LF02                251114
FUEL IDENT.                     FUEL FLOW PPH     MANIFOLD FUEL TEMP FAH 251114
JET-A HC RATIO 0.161             358.             182.2               251114
BELLMOUTH AIR FLOW LB/SEC       CORE AIRFLOW LB/SEC FUEL-AIR RATIO MEAS. 251114
 67.2                            9.7              0.0103              251114
PT3 PSIA                        TT3 DEG. RANKINE                      251114
 33.8                            720.4                                251114
PT9 PSIA                        TT9 DEG RANKINE   EPR                 251114
14.825                          1204.4             2.31               251114
NET THRUST LBS                  N1 RPM            N2 RPM              251114
 396.0                          11168.            1847.               251114
ACTUAL INLET PRESSURE PO PSIA                                         251114
14.628                                                                251114
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                              251114
536.3                                                                 251114
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                   251114
123.9                                                                 251114
FILTER AREA .385 SI                                                   251114
CLEAN CK SMOKE NUMBER 0                                               251114
SMOKE NUMBER        VOL.-LITERS     FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH 251114
      0.0                   3.0         0.52     11.050           87.0 251114
      0.0                   4.0         0.52     11.050           87.0 251114
      0.0                   7.0         0.52     11.099           87.0 251114
      0.0                  11.0         0.52     11.050           87.0 251114
GASEOUS EMISSIONS                                                     251114
                    FID       NDIR       NDIR       CHEMI      CHEMI  251114
                    UHC        CO         CO2        NO         NOX   251114
RANGE                2         2          2          1          1     251114
INSTR GAS TEMP      154.      53.        53.        62.        62.    251114
RAW VALUE MV         15.0     873.5      468.2      408.0      729.5  251114
GAS CONCEN PPM(C)   110.3      441.8      21237.0       10.7       18.7 251114
GAS CONCEN PCT      0.0110    0.0442     2.1237     0.0011     0.0019 251114
EMISSION INDEX       5.06      40.7      3075.          1.6        2.8 251114
FUEL-AIR RATIO      0.0106                                            251114
```

```
                                                                                   261105
ENGINE TEST CATA                                                                   261105
DATE                         CATA PCINT           TEST CELL                        261105
C8/13/76                     2611C5               13                               261105
INSTRUMENT CFERATOR                               TEST OPERATOR                    261105
ERHARDT                                           TREMBLEY                         261105
ENGINE MANUFACTURER          MODEL                SERIAL NUMBER                    261105
LYCCMING                     ALF-502              LF02                             261105
FUEL IDENT.                  FUEL FLCW PPH        MANIFCLD FUEL TEMP FAH           261105
JET-A HC RATIO C.161          359.                159.6                            261105
BELLMOUTH AIR FLCW LB/SEC    CORE AIRFLCW LB/SEC  FUEL-AIR RATIO MEAS.             261105
 67.1                         9.8                 C.0102                           261105
FT3 PSIA                     TT3 CEG. RANKINE                                      261105
 33.8                         717.3                                                261105
FT9 PSIA                     TT9 DEG RANKINE      EPR                              261105
14.820                       1197.3                2.31                            261105
NET THRUST LBS               N1 RPM               N2 RPM                           261105
 395.0                       11148.               1856.                            261105
ACTUAL INLET PRESSURE FC PSIA                                                      261105
14.625                                                                             261105
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                                           261105
534.1                                                                              261105
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                                261105
118.0                                                                              261105
FILTER AREA .385 SI                                                                261105
CLEAN CK SMCKE NUMBER C                                                            261105
SMOKE NUMBER         VCL.-LITERS    FLCW-CFM  PRESS.-PSIA  TEMP. DEG.FAH           261105
        0.0                  3.0        0.52       11.048           84.0           261105
        2.3                  4.C        C.52       11.048           84.0           261105
        2.3                  7.0        C.50       11.048           84.0           261105
        4.5                 11.C        C.50       11.048           84.0           261105
GASEOUS EMISSICNS                                                                  261105
                    FID         NDIR        NDIR        CHEMI       CHEMI          261105
                    UHC          CO         CO2          NO          NOX           261105
RANGE                2           2           2            1           1            261105
INSTR GAS TEMP      153.        53.         53.          62.         62.           261105
RAW VALLE MV         17.1       896.5       465.0        408.3       72C.7         261105
GAS CCNCEN PPM(C)    125.5       455.4       21032.6        1C.8        18.7       261105
GAS CCNCEN PCT      C.0126      0.0455      2.1033       0.0011      0.0019        261105
EMISSION INCEX       5.81        42.3       3070.           1.6         2.9        261105
FUEL-AIF PATIO      C.0105
```

```
ENGINE TEST DATA                                                              266705
DATE                          DATA POINT       TEST CELL                      266705
08/13/76                      266705           13                             266705
INSTRUMENT OPERATOR                            TEST OPERATOR                  266705
ERHARDT                                        TREMBLEY                       266705
ENGINE MANUFACTURER           MODEL            SERIAL NUMBER                  266705
LYCOMING                      ALF-502          LF02                           266705
FUEL IDENT.                   FUEL FLOW PPH    MANIFOLD FUEL TEMP FAH         266705
JET-A HC RATIO 0.0            2544.            237.0                          266705
BELLMOUTH AIR FLOW LB/SEC     CORE AIRFLOW LB/SEC FUEL-AIR RATIO MEAS.        266705
232.1                         33.9             0.0209                         266705
PT3 PSIA                      TT3 DEG. RANKINE                                266705
154.4                        1161.6                                           266705
PT9 PSIA                      TT9 DEG RANKINE  EPR                            266705
18.265                        1614.5           10.63                          266705
NET THRUST LBS                N1 RPM           N2 RPM                         266705
5985.0                        19490.           6259.                          266705
ACTUAL INLET PRESSURE PO PSIA                                                 266705
14.560                                                                        266705
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                                      266705
532.5                                                                         266705
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                           266705
119.0                                                                         266705
FILTER AREA .385 SI                                                           266705
CLEAN CK SMOKE NUMBER 0                                                       266705
SMOKE NUMBER        VOL.-LITERS    FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH        266705
        20.6                3.0        0.53     11.148              84.0      266705
        20.6                4.0        0.52     11.148              84.0      266705
        30.8                7.0        0.52     11.197              83.0      266705
        35.4               11.0        0.52     11.197              84.0      266705
GASEOUS EMISSIONS                                                             266705
                    FID        NDIR       NDIR       CHEMI      CHEMI         266705
                    UHC         CO        CO2         NO         NOX          266705
RANGE                1          1          2          3          3            266705
INSTR GAS TEMP      153.        53.        53.        62.        62.          266705
RAW VALUE MV          4.7      120.4      891.2      388.2      418.7         266705
GAS CONCEN PPM(C)     1.5        8.7     45169.1      100.7      108.6        266705
GAS CONCEN PCT      0.0002     0.0009     4.5169     0.0101     0.0109        266705
EMISSION INDEX      0.03        0.4      3154.         7.4        7.9         266705
FUEL-AIR RATIO      0.0222                                                    266705
```

```
ENGINE TEST CATA                                                            268605
DATE                      CATA POINT          TEST CELL                     268605
C8/13/76                  2686C5              13                            268605
INSTRUMENT CFERATOR                           TEST OPERATOR                 268605
ERHARDT                                       TREMBLEY                      268605
ENGINE MANUFACTURER       MCDEL               SERIAL NUMBER                 268605
LYCCMING                  ALF-502             LF02                          268605
FUEL ICENT.               FUEL FLCW PPH       MANIFOLC FUEL TEMP FAH        268605
JET-A HC RATIO 0.161      2263.               243.5                         268605
BELLMCUTH AIR FLCW LB/SEC CORE AIRFLOW LB/SEC FUEL-AIR RATIO MEAS.          268605
222.2                     31.9                0.0197                        268605
PT3 PSIA                  TT3 DEG. RANKINE                                  268605
143.7                    1134.5                                             268605
PT9 PSIA                  TT9 DEG RANKINE     EPR                           268605
17.722                    1559.9               9.89                         268605
NET THRUST LBS            N1 RPM              N2 RPM                        268605
5402.0                    19160.              6020.                         268605
ACTUAL INLET PRESSURE PC PSIA                                               268605
14.556                                                                      268605
ACTUAL INLET TEMPERATURE TC DEG. RANKINE                                    268605
532.7                                                                       268605
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                         268605
121.1                                                                       268605
FILTER AREA .385 SI                                                         268605
CLEAN CK SMCKE NUMBER 0                                                     268605
SMOKE NUMBER     VOL.-LITERS     FLCW-CFM PRESS.-PSIA  TEMP. DEG.FAH        268605
      18.7              3.0          0.52     11.149            85.0        268605
      22.4              4.0          0.52     11.149            85.0        268605
      30.8              7.0          0.53     11.149            85.0        268605
      38.3             11.0          0.53     11.198            85.0        268605
GASEOUS EMISSICNS                                                           268605
                 FID       NDIR      NDIR       CHEMI     CHEMI             268605
                 UHC        CC        CO2        NO        NOX              268605
RANGE             1         1         2          2         2                268605
INSTR GAS TEMP   153.      53.       53.        62.       62.               268605
RAW VALUE MV       4.0     97.2      845.9      808.0     876.4             268605
GAS CCNCEN PPM(C)    1.0      6.7    42234.C       88.9      96.4           268605
GAS CCNCEN PCT   C.0001    0.0007    4.2234     0.0089    0.0096            268605
EMISSICN INDEX   0.02       C.3      3154.         6.9       7.5            268605
FUEL-AIR RATIC   C.0208                                                     268605
```

```
ENGINE TEST CATA                                                                  267505
CATE                             CATA PCINT          TEST CELL                    267505
C8/13/76                         267505              13                           267505
INSTRUMENT CFERATOR                                  TEST OPERATOR                267505
ERHARDT                                              TREMBLEY                     267505
ENGINE MANUFACTURER              MODEL               SERIAL NUMBER                267505
LYCCMING                         ALF-502             LF02                         267505
FUEL IDENT.                      FUEL FLCW PPH       MANIFCLC FUEL TEMP FAH       267505
JET-A HC RATIO C.161             1259.               244.2                        267505
BELLMCLTH AIR FLCW LB/SEC        CORE AIRFLCW LB/SEC FUEL-AIR RATIO MEAS.         267505
171.4                            24.7                0.0142                       267505
PT3 PSIA                         TT3 CEG. RANKINE                                 267505
100.6                           1014.5                                            267505
PT9 PSIA                         TT9 DEG RANKINE     EPR                          267505
16.073                           1302.6               6.90                        267505
NET THRLST LBS                   N1 RPM              N2 RPM                       267505
3087.0                           17336.              4727.                        267505
ACTUAL INLET FRESSLRE PO PSIA                                                     267505
14.59C                                                                            267505
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                                          267505
532.8                                                                             267505
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                               267505
120.0                                                                             267505
FILTER AREA .385 SI                                                               267505
CLEAN CK SMCKE NUMBER C                                                           267505
SMOKE NUMBER       VOL.-LITERS      FLCW-CFM PRESS.-PSIA   TEMP. DEG.FAH          267505
      10.9                 3.0          0.52    11.149              85.0          267505
      14.9                 4.0          C.53    11.198              85.0          267505
      22.4                 7.0          C.53    11.198              85.0          267505
      27.6                11.0          0.53    11.198              85.0          267505
GASEOUS EMISSICNS                                                                 267505
                   FID          NCIR       NCIR       CHEMI       CHEMI           267505
                   UHC          CC         CO2        NO          NOX             267505
RANGE               1           1          2          2           2               267505
INSTR GAS TEMP     154.         53.        53.        62.         62.             267505
RAW VALLE MV         4.6        379.9      623.7      442.9       491.9           267505
GAS CCNCEN PPM(C)    1.5         34.5      29392.4       48.8        54.1         267505
GAS CCNCEN PCT     C.CCC2       0.0034     2.9392     0.CC49      0.0054          267505
EMISSION INDEX      0.05          2.4      3151.          5.5         6.1         267505
FUEL-AIR RATIO     C.0144                                                         267505
```

```
ENGINE TEST DATA                                                               264405
DATE                     DATA POINT          TEST CELL                         264405
08/13/76                 264405              13                                264405
INSTRUMENT OPERATOR                          TEST OPERATOR                     264405
ERHARDT                                      TREMBLEY                          264405
ENGINE MANUFACTURER      MODEL               SERIAL NUMBER                     264405
LYCOMING                 ALF-502             LF02                              264405
FUEL IDENT.              FUEL FLOW PPH       MANIFOLD FUEL TEMP FAH            264405
JET-A HC RATIO 0.161     1095.               233.8                             264405
BELLMOUTH AIR FLOW LB/SEC CORE AIRFLOW LB/SEC FUEL-AIR RATIO MEAS.             264405
106.4                    23.2                0.0131                            264405
PT3 PSIA                 TT3 DEG. RANKINE                                      264405
 92.2                      986.7                                               264405
PT9 PSIA                 TT9 DEG RANKINE     EPR                               264405
15.866                   1302.6               6.32                             264405
NET THRUST LBS           N1 RPM              N2 RPM                            264405
2651.0                   16906.              4419.                             264405
ACTUAL INLET PRESSURE PO PSIA                                                  264405
14.586                                                                         264405
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                                       264405
532.5                                                                          264405
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                            264405
123.0                                                                          264405
FILTER AREA .385 SI                                                            264405
CLEAN CK SMOKE NUMBER 0                                                        264405
SMOKE NUMBER          VOL.-LITERS    FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH       264405
       8.8                    3.0        0.52     11.198             84.0      264405
      12.9                    4.0        0.53     11.149             84.0      264405
      18.7                    7.0        0.53     11.149             84.0      264405
      24.1                   11.0        0.53     11.149             84.0      264405
GASEOUS EMISSIONS                                                              264405
                  FID        NDIR       NDIR       CHEMI      CHEMI            264405
                  UHC         CO         CO2        NO         NOX             264405
RANGE              1          1          2          2          2               264405
INSTR GAS TEMP    153.       56.        56.        62.        62.              264405
RAW VALUE MV        5.9      547.5      582.5      389.6      446.3            264405
GAS CONCEN PPM(C)     2.8       52.3     27212.9       42.6       48.7         264405
GAS CONCEN PCT    0.0003     0.0052     2.7213     0.0043     0.0049           264405
EMISSION INDEX     0.10        3.9      3148.         5.2        5.9           264405
FUEL-AIR RATIO    0.0133                                                       264405
```

```
ENGINE TEST CATA                                                     263305
DATE                     CATA PCINT          TEST CELL               263305
C8/13/76                 2633C5              13                      263305
INSTRUMENT OPERATCR                          TEST OPERATOR           263305
ERHARDT                                      TREMBLEY                263305
ENGINE MANUFACTURER      MODEL               SERIAL NLMBER           263305
LYCCMING                 ALF-502             LF02                    263305
FUEL IDENT.              FUEL FLCW PPH       MANIFOLC FUEL TEMP FAH  263305
JET-A HC RATIO 0.161      765.               221.6                   263305
BELLMCUTH AIR FLOW LB/SEC CORE AIRFLOW LB/SEC FUEL-AIR RATIO MEAS.   263305
130.9                    18.9                0.0112                  263305
PT3 PSIA                 TT3 DEG. RANKINE                            263305
 72.3                     917.1                                      263305
PT9 PSIA                 TT9 DEG RANKINE     EPR                     263305
15.4C8                   12C5.0               4.95                   263305
NET THRLST LBS           N1 RPM              N2 RPM                  263305
1722.0                   15652.              3617.                   263305
ACTUAL INLET PRESSURE FC PSIA                                        263305
14.607                                                               263305
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                             263305
533.0                                                                263305
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                  263305
121.9                                                                263305
FILTER AREA .385 SI                                                  263305
CLEAN CK SMCKE NUMBER 0                                              263305
SMOKE NUMBER      VCL.-LITERS      FLCW-CFM PRESS.-PSIA  TEMP. DEG.FAH  263305
        6.7               3.0          0.52      11.100          84.0   263305
        6.7               4.0          0.52      11.10C          84.0   2633C5
        8.8               7.0          0.52      11.100          84.0   263305
       14.9              11.0          0.53      11.149          84.0   2633C5
GASEOLS EMISSIONS                                                       263305
                   FID          NDIR       NDIR       CHEMI      CHEMI  263305
                   UHC          CC          CO2        NO         NOX   263305
RANGE               1            2          2          2          2     263305
INSTR GAS TEMP     153.          56.        56.        62.        62.   263305
RAW VALUE MV        20.4        305.7      456.0      255.0      329.9  263305
GAS CCNCEN PPM(C)     13.7       127.0      22660.8       27.9      36.0  263305
GAS CCNCEN FCT     0.0014       0.C127     2.2661     0.0028     0.C036 263305
EMISSION INCEX       0.6C        11.2      3135.         4.0        5.2  263305
FUEL-AIR RATIO     C.C111                                               263305
```

```
ENGINE TEST DATA                                                                    262205
DATE                           DATA POINT          TEST CELL                        262205
08/13/76                       262205              13                               262205
INSTRUMENT OPERATOR                                TEST OPERATOR                    262205
ERHARDT                                            TREMBLEY                         262205
ENGINE MANUFACTURER            MODEL               SERIAL NUMBER                    262205
LYCOMING                       ALF-502             LF02                             262205
FUEL IDENT.                    FUEL FLOW PPH       MANIFOLD FUEL TEMP FAH           262205
JET-A HC RATIO 0.161            436.               187.6                            262205
BELLMOUTH AIR FLOW LB/SEC      CORE AIRFLOW LB/SEC FUEL-AIR RATIO MEAS.             262205
 81.0                          11.8                0.0103                           262205
PT3 PSIA                       TT3 DEG. RANKINE                                     262205
 40.9                           762.5                                               262205
PT9 PSIA                       TT9 DEG RANKINE     EPR                              262205
14.906                         1194.8               2.79                            262205
NET THRUST LBS                 N1 RPM              N2 RPM                           262205
 599.0                         12530.              2216.                            262205
ACTUAL INLET PRESSURE PO PSIA                                                       262205
14.626                                                                              262205
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                                            262205
533.3                                                                               262205
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                                 262205
121.8                                                                               262205
FILTER AREA .385 SI                                                                 262205
CLEAN CK SMOKE NUMBER 0                                                             262205
SMOKE NUMBER        VOL.-LITERS     FLOW-CFM PRESS.-PSIA   TEMP. DEG.FAH            262205
         0.0                3.0         0.52     11.050              83.0           262205
         0.0                4.0         0.52     11.100              83.0           262205
         2.3                7.0         0.50     11.050              83.0           262205
         6.7               11.0         0.52     11.050              83.0           262205
GASEOUS EMISSIONS                                                                   262205
                    FID          NDIR         NDIR         CHEMI        CHEMI       262205
                    UHC          CO           CO2          NO           NOX         262205
RANGE               1            2            2            1            1           262205
INSTR GAS TEMP      153.         56.          56.          62.          62.         262205
RAW VALUE MV        109.3        750.5        469.9        492.9        827.3       262205
GAS CONCEN PPM(C)    80.7        371.5        21314.5        12.9         21.4      262205
GAS CONCEN PCT      0.0081       0.0371       2.1314       0.0013       0.0021      262205
EMISSION INDEX       3.71         34.3        3089.          2.0          3.2       262205
FUEL-AIR RATIO      0.0106                                                          262205
```

```
ENGINE TEST CATA                                                         261115
DATE                          CATA PCINT          TEST CELL              261115
C8/13/76                      261115              13                     261115
INSTRUMENT OPERATOR                               TEST OPERATOR          261115
ERHARCT                                           TREMBLEY               261115
ENGINE MANUFACTURER           MCDEL               SERIAL NUMBER          261115
LYCCMING                      ALF-502             LF02                   261115
FUEL IDENT.                   FUEL FLCW PPH       MANIFOLC FUEL TEMP FAH 261115
JET-A HC RATIO C.161           356.               173.9                  261115
BELLMOUTH AIR FLOW LB/SEC     CORE AIRFLOW LB/SEC FUEL-AIR RATIO MEAS.   261115
 66.4                          9.6                0.0103                 261115
PT3 PSIA                      TT3 DEG. RANKINE                           261115
 33.8                          715.8                                     261115
PT9 PSIA                      TT9 DEG RANKINE     EPR                    261115
14.828                        1199.4               2.31                  261115
NET THRLST LBS                N1 RPM              N2 RPM                 261115
 397.0                        11122.              1838.                  261115
ACTUAL INLET PRESSLRE PC PSIA                                            261115
14.633                                                                   261115
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                                 261115
533.3                                                                    261115
SPECIFIC HUMIDITY GRAINS/LB CRY AIR                                      261115
121.3                                                                    261115
FILTER AREA .385 SI                                                      261115
CLEAN CK SMCKE NUMBER 0                                                  261115
SMOKE NUMBER          VOL.-LITERS     FLCW-CFM PRESS.-PSIA  TEMP. DEG.FAH 261115
         2.3                  3.0          C.50     11.C49          83.0 261115
         2.3                  4.0          C.52     11.049          83.0 261115
         2.3                  7.C          0.52     11.049          83.0 261115
         4.5                 11.0          C.52     11.C49          83.C 261115
GASEOLS EMISSICNS                                                        261115
                    FID        NDIR        NDIR        CHEMI     CHEMI   261115
                    UHC         CO          CO2         NO        NOX    261115
RANGE               2          2            2           1         1      261115
INSTR GAS TEMP      154.       56.          56.         62.       62.    261115
RAW VALUE MV         16.7      897.8        464.1       399.8     721.6  261115
GAS CCNCEN PPM(C)    123.8      454.3        21017.4       10.5      18.7 261115
GAS CCNCEN PCT      C.0124     0.C454       2.1017      0.0011    0.C019 261115
EMISSICN INDEX       5.73       42.2        3070.          1.6       2.9 261115
FUEL-AIR RATIO      C.0105                                               261115
```

```
ENGINE TEST CATA                                                                      271106
DATE                           CATA PCINT            TEST CELL                        271106
C8/14/76                       2711C6                13                               271106
INSTRUMENT OPERATOR                                  TEST OPERATOR                    271106
ERHARDT                                              TREMBLEY                         271106
ENGINE MANUFACTURER            MODEL                 SERIAL NUMBER                    271106
LYCCMING                       ALF-502               LFC2                             271106
FUEL IDENT.                    FUEL FLCW PPH         MANIFOLC FUEL TEMP FAH           271106
JET-A HC RATIO C.161            377.                 168.4                            271106
BELLMCUTH AIR FLCW LB/SEC      CORE AIRFLCW LB/SEC   FUEL-AIR RATIO MEAS.             271106
 66.4                          9.2                   0.0114                           271106
PT3 PSIA                       TT3 DEG. RANKINE                                       271106
 33.2                           716.0                                                 271106
PT9 PSIA                       TT9 DEG RANKINE       EPR                              271106
14.866                         1264.0                 2.27                            271106
NET THRUST LBS                 N1 RFM                N2 RPM                           271106
 399.0                         10934.                1868.                            271106
ACTUAL INLET PRESSURE PC PSIA                                                         271106
14.684                                                                                271106
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                                              271106
538.2                                                                                 271106
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                                   271106
113.5                                                                                 271106
FILTER AREA .385 SI                                                                   2711C6
CLEAN CK SMCKE NUMBER 0                                                               271106
SMCKE NUMBER         VCL.-LITERS      FLCW-CFM PRESS.-PSIA  TEMP. DEG.FAH             271106
          0.0                 3.0           0.52     11.090            84.0           271106
          0.0                 4.C           C.52     11.139            84.0           271106
          2.3                 7.0           0.53     11.139            84.0           271106
          2.3                11.0           C.52     11.139            84.0           271106
GASEOUS EMISSICNS                                                                     271106
                     FID          NDIR         NCIR         CHEMI       CHEMI         271106
                     UHC           CC          CO2           NO          NOX          271106
RANGE                 1            2            2            1           1            271106
INSTR GAS TEMP       153.         55.          55.          62.         62.           271106
RAW VALLE MV         137.8        889.1        515.0        450.1       814.8         271106
GAS CCNCEN PPM(C)     101.9        447.6        23312.C        11.7        20.9       271106
GAS CCNCEN PCT       C.0102       0.C448       2.3312       C.CC12      0.C021        2711C6
EMISSICN INDEX        4.27         37.7        3082.           1.6         2.9        271106
FUEL-AIR RATIO       C.0116                                                           271106
```

```
ENGINE TEST DATA                                                                  276706
DATE                           DATA POINT               TEST CELL                 276706
08/14/76                       276706                   13                        276706
INSTRUMENT OPERATOR                                     TEST OPERATOR             276706
ERHARDT                                                 TREMBLEY                  276706
ENGINE MANUFACTURER            MODEL                    SERIAL NUMBER             276706
LYCOMING                       ALF-502                  LF02                      276706
FUEL IDENT.                    FUEL FLOW PPH            MANIFOLD FUEL TEMP FAH    276706
JET-A HC RATIO 0.161           2485.                    240.6                     276706
BELLMOUTH AIR FLOW LB/SEC      CORE AIRFLOW LB/SEC      FUEL-AIR RATIO MEAS.      276706
227.9                          33.0                     0.0209                    276706
PT3 PSIA                       TT3 DEG. RANKINE                                   276706
150.7                         1159.1                                              276706
PT9 PSIA                       TT9 DEG RANKINE          EPR                       276706
18.103                         1616.7                   10.34                     276706
NET THRUST LBS                 N1 RPM                   N2 RPM                    276706
5828.0                         19384.                   6223.                     276706
ACTUAL INLET PRESSURE PC PSIA                                                     276706
14.587                                                                            276706
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                                          276706
535.8                                                                             276706
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                               276706
111.9                                                                             276706
FILTER AREA .385 SI                                                               276706
CLEAN CK SMOKE NUMBER 0                                                           276706
SMOKE NUMBER        VOL.-LITERS      FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH          276706
        14.9                3.0          0.53      11.237           85.0          276706
        22.4                4.0          0.53      11.237           85.0          276706
        27.6                7.0          0.54      11.237           85.0          276706
        36.9               11.0          0.53      11.237           85.0          276706
GASEOUS EMISSIONS                                                                 276706
                    FID         NDIR        NDIR        CHEMI       CHEMI         276706
                    UHC          CO          CO2         NO          NOX          276706
RANGE                1           1           2           3           3            276706
INSTR GAS TEMP      153.        54.         54.         62.         62.           276706
RAW VALUE MV          8.2       120.2       699.8       397.1       421.7         276706
GAS CONCEN PPM(C)      4.2         8.8     45127.8       102.6       109.0        276706
GAS CONCEN PCT      0.0004      0.0009      4.5128      0.0103      0.0109        276706
EMISSION INDEX       0.09         0.4       3154.          7.5         8.0        276706
FUEL-AIR RATIO      0.0222                                                        276706
```

```
ENGINE TEST DATA                            278606
DATE              DATA POINT  TEST CELL     278606
08/14/76          278606      13            278606
INSTRUMENT OPERATOR           TEST OPERATOR 278606
ERHARDT                       TREMBLEY      278606
ENGINE MANUFACTURER MODEL     SERIAL NUMBER 278606
LYCOMING          ALF-502     LF02          278606
FUEL IDENT.       FUEL FLOW PPH MANIFOLD FUEL TEMP FAH 278606
JET-A HC RATIO 0.161 2158.    249.5         278606
BELLMOUTH AIR FLOW LB/SEC CORE AIRFLOW LB/SEC FUEL-AIR RATIO MEAS. 278606
217.7             31.2        0.0196        278606
PT3 PSIA          TT3 DEG. RANKINE          278606
140.3            1134.1                     278606
PT9 PSIA          TT9 DEG RANKINE EPR       278606
17.595            1567.6       9.63         278606
NET THRUST LBS    N1 RPM      N2 RPM        278606
5250.0            19052.      5962.         278606
ACTUAL INLET PRESSURE PC PSIA               278606
14.598                                      278606
ACTUAL INLET TEMPERATURE TC DEG. RANKINE    278606
537.0                                       278606
SPECIFIC HUMIDITY GRAINS/LB DRY AIR         278606
109.9                                       278606
FILTER AREA .385 SI                         278606
CLEAN CK SMOKE NUMBER 0                     278606
SMOKE NUMBER  VOL.-LITERS  FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH 278606
     16.8             3.0     0.53   11.237          85.0 278606
     20.6             4.0     0.53   11.188          85.0 278606
     30.8             7.0     0.55   11.188          85.0 278606
     35.4            11.0     0.53   11.237          85.0 278606
GASEOUS EMISSIONS                           278606
            FID   NDIR   NDIR   CHEMI  CHEMI 278606
            UHC   CO     CO2    NO     NOX   278606
RANGE        1     1      2      2      2    278606
INSTR GAS TEMP 153. 53.  53.    62.    62.   278606
RAW VALUE MV  7.2  96.2  850.5  827.9  900.2 278606
GAS CONCEN PPM(C) 3.4 6.7 41966.1  90.8  98.7 278606
GAS CONCEN PCT 0.0003 0.0007 4.1966 0.0091 0.0099 278606
EMISSION INDEX 0.08 0.3  3154.    7.1    7.8  278606
FUEL-AIR RATIO 0.0206                       278606
```

```
ENGINE TEST DATA                                                                    277506
DATE                          DATA POINT               TEST CELL                    277506
08/14/76                      277506                   13                           277506
INSTRUMENT OPERATOR                                    TEST OPERATOR                277506
ERHARDT                                                TREMBLEY                     277506
ENGINE MANUFACTURER           MODEL                    SERIAL NUMBER                277506
LYCOMING                      ALF-502                  LF02                         277506
FUEL IDENT.                   FUEL FLOW PPH            MANIFOLD FUEL TEMP FAH       277506
JET-A HC RATIO 0.161          1208.                    249.4                        277506
BELLMOUTH AIR FLOW LB/SEC     CORE AIRFLOW LB/SEC      FUEL-AIR RATIO MEAS.         277506
165.2                         24.0                     0.0140                       277506
PT3 PSIA                      TT3 DEG. RANKINE                                      277506
 97.0                        1010.8                                                 277506
PT9 PSIA                      TT9 DEG RANKINE          EPR                          277506
16.024                        1358.6                    6.64                        277506
NET THRUST LBS                N1 RPM                   N2 RPM                       277506
2930.0                        17176.                   4649.                        277506
ACTUAL INLET PRESSURE PO PSIA                                                       277506
14.631                                                                              277506
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                                            277506
537.2                                                                               277506
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                                 277506
108.1                                                                               277506
FILTER AREA .385 SI                                                                 277506
CLEAN CK SMOKE NUMBER 0                                                             277506
SMOKE NUMBER        VOL.-LITERS     FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH             277506
        8.8                 3.0         0.52     11.087             85.0            277506
       10.9                 4.0         0.52     11.087             85.0            277506
       20.6                 7.0         0.50     11.087             85.0            277506
       27.6                11.0         0.50     11.087             85.0            277506
GASEOUS EMISSIONS                                                                   277506
                    FID        NDIR        NDIR       CHEMI       CHEMI             277506
                    UHC         CO          CO2         NO         NOX              277506
RANGE                1          1           2          2           2                277506
INSTR GAS TEMP      154.       53.         53.        62.         62.               277506
RAW VALUE MV          8.3     372.8       627.2      461.8       511.9              277506
GAS CONCEN PPM(C)     4.2      33.9     29212.7         50.5        56.0            277506
GAS CONCEN PCT      0.0004    0.0034     2.9213     0.0051      0.0056              277506
EMISSION INDEX       0.14       2.3      3151.         5.7         6.3              277506
FUEL-AIR RATIO      0.0143                                                          277506
```

```
ENGINE TEST DATA                                                     274406
DATE                      DATA POINT          TEST CELL              274406
08/14/76                  274406              13                     274406
INSTRUMENT OPERATOR                           TEST OPERATOR          274406
ERHARDT                                       TREMBLEY               274406
ENGINE MANUFACTURER       MODEL               SERIAL NUMBER          274406
LYCOMING                  ALF-502             LF02                   274406
FUEL IDENT.               FUEL FLOW PPH       MANIFOLD FUEL TEMP FAH 274406
JET-A HC RATIO 0.161      1038.               236.7                  274406
BELLMOUTH AIR FLOW LB/SEC CORE AIRFLOW LB/SEC FUEL-AIR RATIO MEAS.   274406
153.4                     22.0                0.0131                 274406
PT3 PSIA                  TT3 DEG. RANKINE                           274406
 87.3                      980.8                                     274406
PT9 PSIA                  TT9 DEG RANKINE     EPR                    274406
15.774                    1311.9               5.96                  274406
NET THRUST LBS            N1 RPM              N2 RPM                 274406
2436.0                    16682.              4264.                  274406
ACTUAL INLET PRESSURE PO PSIA                                        274406
14.639                                                               274406
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                             274406
539.0                                                                274406
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                  274406
110.7                                                                274406
FILTER AREA .385 SI                                                  274406
CLEAN CK SMOKE NUMBER 0                                              274406
SMOKE NUMBER       VOL.-LITERS    FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH  274406
      10.9                 3.0        0.52     11.087            86.0  274406
      12.9                 4.0        0.52     11.137            86.0  274406
      14.9                 7.0        0.52     11.137            86.0  274406
      24.1                11.0        0.52     11.137            86.0  274406
GASEOUS EMISSIONS                                                    274406
                   FID        NDIR        NDIR        CHEMI     CHEMI    274406
                   UHC         CO          CO2         NO        NOX     274406
RANGE               1           1           2           2         2      274406
INSTR GAS TEMP     153.        54.         54.         62.       62.     274406
RAW VALUE MV         9.6       565.8       565.0       392.6     456.2   274406
GAS CONCEN PPM(C)    3.3        55.0     27112.3        43.1      50.1   274406
GAS CONCEN PCT     0.0003     0.0055      2.7112     0.0043    0.0050    274406
EMISSION INDEX      0.12         4.1      3148.          5.2       6.1   274406
FUEL-AIR RATIO     0.0133                                            274406
```

```
ENGINE TEST DATA                                                                    273306
DATE                          DATA POINT            TEST CELL                       273306
08/14/76                      273306                13                              273306
INSTRUMENT OPERATOR                                                                 273306
ERHARDT                                             TEST OPERATOR                   273306
                                                    TREMBLEY                        273306
ENGINE MANUFACTURER           MODEL                 SERIAL NUMBER                   273306
LYCOMING                      ALF-502               LF02                            273306
FUEL IDENT.                   FUEL FLOW PPH         MANIFOLD FUEL TEMP FAH          273306
JET-A HC RATIO 0.161           702.                 225.8                           273306
BELLMOUTH AIR FLOW LB/SEC     CORE AIRFLOW LB/SEC   FUEL-AIR RATIO MEAS.            273306
122.2                         17.6                  0.0111                          273306
PT3 PSIA                      TT3 DEG. RANKINE                                      273306
 66.9                          903.3                                                273306
PT9 PSIA                      TT9 DEG RANKINE       EPR                             273306
15.330                        1215.4                 4.57                           273306
NET THRUST LBS                N1 RPM                N2 RPM                          273306
1533.0                        15196.                3419.                           273306
ACTUAL INLET PRESSURE PO PSIA                                                       273306
14.651                                                                              273306
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                                            273306
538.0                                                                               273306
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                                 273306
111.0                                                                               273306
FILTER AREA .385 SI                                                                 273306
CLEAN CK SMOKE NUMBER 0                                                             273306
SMOKE NUMBER        VOL.-LITERS     FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH             273306
       4.5                  3.0         0.52   11.086              85.0             273306
       4.5                  4.0         0.53   11.135              85.0             273306
      10.9                  7.0         0.52   11.135              85.0             273306
      12.9                 11.0         0.52   11.135              85.0             273306
GASEOUS EMISSIONS                                                                   273306
                    FID        NDIR        NDIR        CHEMI       CHEMI            273306
                    UHC        CO          CO2         NO          NOX              273306
RANGE               1          2           2           2           2                273306
INSTR GAS TEMP      154.       54.         54.         62.         62.              273306
RAW VALUE MV         25.3      342.3       499.2       245.4       327.0            273306
GAS CONCEN PPM(C)    15.4       143.2       22627.4        27.0        35.9         273306
GAS CONCEN PCT      0.0015     0.0143      2.2627      0.0027      0.0036           273306
EMISSION INDEX      0.68        12.6       3133.          3.9          5.2          273306
FUEL-AIR RATIO      0.0111                                                          273306
```

```
ENGINE TEST CATA                                                          272206
CATE                        CATA POINT          TEST CELL                 272206
C8/14/76                    272206              13                        272206
INSTRUMENT CPERATOR                             TEST CPERATOR             272206
ERHARDT                                         TREMBLEY                  272206
ENGINE MANUFACTURER         MODEL               SERIAL NUMBER             272206
LYCOMING                    ALF-502             LF02                      272206
FUEL IDENT.                 FUEL FLCW PPH       MANIFCLD FUEL TEMP FAH    272206
JET-A HC RATIO 0.161         452.               193.2                     272206
BELLMCUTH AIR FLCW LB/SEC   CORE AIRFLOW LB/SEC FUEL-AIR RATIO MEAS.      272206
 78.4                       11.4                0.0111                    272206
PT3 PSIA                    TT3 DEG. RANKINE                              272206
 39.9                        764.7                                        272206
PT9 PSIA                    TT9 DEG RANKINE     EPR                       272206
14.934                      1253.0               2.72                     272206
NET THRLST LBS              N1 RPM              N2 RPM                    272206
 595.0                      12336.              2211.                     272206
ACTUAL INLET PRESSURE PO PSIA                                             272206
14.664                                                                    272206
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                                  272206
540.4                                                                     272206
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                       272206
110.9                                                                     272206
FILTER AREA .385 SI                                                       272206
CLEAN CK SMCKE NUMBER 0                                                   272206
SMOKE NUMBER       VOL.-LITERS     FLCW-CFM PRESS.-PSIA  TEMP. DEG.FAH    272206
        0.0                3.0          0.52    11.C85              85.0  272206
        0.C                4.C          0.50    11.C85              85.0  272206
        2.3                7.C          0.52    11.C85              85.0  272206
        4.5               11.0          0.52    11.135              85.0  272206
GASEOUS EMISSIONS                                                         272206
                   FID        NDIR        NDIR       CHEMI      CHEMI     272206
                   UHC        CC          CO2        NO         NOX       272206
RANGE              1          2           2          1          1         272206
INSTR GAS TEMP     154.       53.         53.        62.        62.       272206
RAW VALLE MV        86.3      725.4       509.7      547.6      912.4     272206
GAS CCNCEN PPM(C)    62.2      356.8      23166.6      14.3       23.5    272206
GAS CCNCEN PCT     0.C062     0.C357      2.3167     0.C014     0.C024    272206
EMISSION INDEX      2.64       30.4       3099.        2.0        3.3     272206
FUEL-AIR RATIO     0.0115                                                 272206
```

```
                                                                           271116
ENGINE TEST DATA                                                           271116
DATE                      DATA POINT           TEST CELL                   271116
08/14/76                  271116               13                          271116
INSTRUMENT OPERATOR                            TEST OPERATOR               271116
ERHARDT                                        TREMBLEY                    271116
ENGINE MANUFACTURER       MODEL                SERIAL NUMBER               271116
LYCOMING                  ALF-502              LF02                        271116
FUEL IDENT.               FUEL FLOW PPH        MANIFOLD FUEL TEMP FAH      271116
JET-A HC RATIO 0.161       379.                177.7                       271116
BELLMOUTH AIR FLOW LB/SEC CORE AIRFLOW LB/SEC  FUEL-AIR RATIO MEAS.        271116
 65.7                      9.3                 0.0114                      271116
PT3 PSIA                  TT3 DEG. RANKINE                                 271116
 33.0                      716.4                                           271116
PT9 PSIA                  TT9 DEG RANKINE       EPR                        271116
14.853                    1273.3                 2.25                      271116
NET THRUST LBS            N1 RPM               N2 RPM                      271116
 400.0                    10886.               1859.                       271116
ACTUAL INLET PRESSURE P0 PSIA                                              271116
14.670                                                                     271116
ACTUAL INLET TEMPERATURE T0 DEG. RANKINE                                   271116
539.7                                                                      271116
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                        271116
110.9                                                                      271116
FILTER AREA .385 SI                                                        271116
CLEAN CK SMOKE NUMBER 0                                                    271116
SMOKE NUMBER     VOL.-LITERS    FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH        271116
       0.0               3.0        0.50     11.084            86.0        271116
       0.0               4.0        0.50     11.084            86.0        271116
       2.3               7.0        0.52     11.084            86.0        271116
       4.5              11.0        0.50     11.084            86.0        271116
GASEOUS EMISSIONS                                                          271116
                  FID        NDIR       NDIR       CHEMI      CHEMI        271116
                  UHC        CO         CO2        NO         NOX          271116
RANGE             1          2          2          1          1            271116
INSTR GAS TEMP    154.       53.        53.        62.        62.          271116
RAW VALUE MV      141.0      502.7      514.4      439.8      812.9        271116
GAS CONCEN PPM(C)  104.2      456.1      23408.1       11.5       21.0     271116
GAS CONCEN PCT    0.0104     0.0456     2.3408     0.0012     0.0021       271116
EMISSION INDEX     4.35       38.2      3081.          1.6        2.9      271116
FUEL-AIR RATIO    0.0117                                                   271116
```

```
ENGINE TEST CATA                                                          281107
CATE                       CATA PCINT          TEST CELL                  2811C7
C8/16/76                   281107              13                         281107
INSTRUMENT CPERATOR                            TEST CPERATOR              281107
ERHARDT                                        TREMBLEY                   281107
ENGINE MANUFACTLRER        MODEL               SERIAL NUMBER              281107
LYCOMING                   ALF-502             LF02                       281107
FUEL IDENT.                FUEL FLCW PPH       MANIFCLC FUEL TEMP FAH     281107
JET-A HC RATIO C.161        375.               153.8                      281107
BELLMCUTH AIR FLCW LB/SEC  CORE AIRFLCW LB/SEC FUEL-AIR RATIO MEAS.       2811C7
 67.1                       9.5                0.0110                     281107
PT3 PSIA                   TT3 DEG. RANKINE                               281107
 33.4                       701.2                                         281107
PT9 PSIA                   TT9 DEG RANKINE     EPR                        281107
14.904                     1241.3               2.27                      281107
NET THRLST LBS             N1 RPM              N2 RPM                     281107
 415.0                     10818.              1835.                      281107
ACTUAL INLET PRESSLRE PO PSIA                                             281107
14.713                                                                    281107
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                                  281107
525.5                                                                     281107
SPECIFIC HUMIDITY GRAINS/LB CRY AIR                                       281107
 62.4                                                                     2811C7
FILTER AREA .385 SI                                                       281107
CLEAN CK SMCKE NUMBER 0                                                   281107
SMOKE NUMBER        VOL.-LITERS     FLCW-CFM PRESS.-PSIA   TEMP. DEG.FAH  281107
          0.0                3.0         0.48     10.298            74.0  281107
          C.C                4.0         0.48     10.298            74.0  281107
          2.3                7.C         0.48     10.298            74.0  281107
          2.3               11.0         C.48     10.298            74.0  281107
GASECLS EMISSIONS                                                         281107
                    FID         NDIR         NDIR        CHEMI      CHEMI  281107
                    LHC          CC           CO2         NO         NOX   281107
RANGE                2           2            2           1          1     281107
INSTR GAS TEMP      153.        60.          60.         61.        61.    281107
RAW VALLE MV         15.7       950.5        527.7       472.1      872.4  281107
GAS CCNCEN PPM(C)    120.3       486.3       22802.3       11.5       21.3  281107
GAS CONCEN PCT      C.0120      0.0486       2.2802      0.0012     0.0021  281107
EMISSICN INDEX       5.14        41.7        3076.          1.6        3.0  281107
FUEL-AIR RATIC      C.0114                                                281107
```

```
ENGINE TEST CATA
DATE                        CATA POINT              TEST CELL                   2867C7
C8/16/76                    286707                  13                          2867C7
INSTRUMENT CPERATOR                                 TEST OPERATOR               286707
ERHARDT                                             TREMBLEY                    286707
ENGINE MANUFACTURER         MODEL                   SERIAL NUMBER               2867C7
LYCCMING                    ALF-502                 LF02                        286707
FUEL IDENT.                 FUEL FLCW PPH           MANIFOLC FUEL TEMP FAH      286707
JET-A HC RATIO C.161        2582.                   232.3                       2867C7
BELLMCUTH AIR FLCW LE/SEC   CORE AIRFLCW LB/SEC     FUEL-AIR RATIO MEAS.        2867C7
236.6                       34.6                    C.0208                      286707
PT3 PSIA                    TT3 DEG. RANKINE                                    2867C7
157.6                      1145.8                                               2867C7
PT9 PSIA                    TT9 DEG RANKINE         EPR                         2867C7
18.552                      1614.0                  10.79                       286707
NET THRUST LBS              N1 RPM                  N2 RPM                      286707
6245.0                      19378.                  6236.                       286707
ACTUAL INLET PRESSURE FC PSIA                                                   286707
14.627                                                                          2867C7
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                                        286707
523.3                                                                           2867C7
SPECIFIC HLMIDITY GRAINS/LB CRY AIR                                             2867C7
 62.1                                                                           2867C7
FILTER AREA .385 SI                                                             2867C7
CLEAN CK SMCKE NUMBER 0                                                         286707
SMOKE NUMEEF        VOL.-LITERS    FLCW-CFM  PRESS.-PSIA   TEMP. DEG.FAH        2867C7
      16.8                 3.0         C.48      10.30C               74.0      286707
      20.6                 4.0         C.50      10.30C               74.0      286707
      27.6                 7.0         C.50      10.30C               74.0      2867C7
      35.4                11.0         0.50      1C.300               75.C      2867C7
GASEOUS EMISSICNS                                                               286707
                      FID        NDIR       NDIR       CHEMI      CHEMI         286707
                      UHC        CC         CC2        NO         NOX           2867C7
RANGE                 1          1          2          3          3             2867C7
INSTR GAS TEMP        153.       54.        54.        60.        61.           286707
RAW VALUE MV            3.2      142.1      941.0      467.4      503.1         286707
GAS CCNCEN PPM(C)       3.6       11.1      45154.3      115.2      124.1       286707
GAS CCNCEN PCT        C.CCC4     C.C011     4.5154     0.0115     0.C124        2867C7
EMISSICN INDEX        0.C8       C.5        3156.        8.4        9.0         286707
FUEL-AIR RATIC        C.C222                                                    2867C7
                                                                                2867C7
```

```
ENGINE TEST DATA                                                                288607
DATE                        DATA POINT           TEST CELL                      288607
08/16/76                    288607               13                             288607
INSTRUMENT OPERATOR                              TEST OPERATOR                  288607
ERHARDT                                          TREMBLEY                       288607
ENGINE MANUFACTURER         MODEL                SERIAL NUMBER                  288607
LYCOMING                    ALF-502              LF02                           288607
FUEL IDENT.                 FUEL FLOW PPH        MANIFOLD FUEL TEMP FAH         288607
JET-A HC RATIO 0.161        2294.                237.6                          288607
BELLMOUTH AIR FLOW LB/SEC   CORE AIRFLOW LB/SEC  FUEL-AIR RATIO MEAS.           288607
227.6                       32.6                 0.0196                         288607
PT3 PSIA                    TT3 DEG. RANKINE                                    288607
146.1                      1122.8                                               288607
PT9 PSIA                    TT9 DEG RANKINE      EPR                            288607
17.902                      1554.4                9.99                          288607
NET THRUST LBS              N1 RPM               N2 RPM                         288607
5632.0                      19038.               5982.                          288607
ACTUAL INLET PRESSURE PO PSIA                                                   288607
14.649                                                                          288607
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                                        288607
523.3                                                                           288607
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                             288607
 61.5                                                                           288607
FILTER AREA .385 SI                                                             288607
CLEAN CK SMOKE NUMBER 0                                                         288607
SMOKE NUMBER       VOL.-LITERS     FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH          288607
      14.9                 3.0         0.48    10.300             74.0          288607
      22.4                 4.0         0.48    10.300             74.0          288607
      27.6                 7.0         0.48    10.300             74.0          288607
      35.4                11.0         0.48    10.300             74.0          288607
GASEOUS EMISSIONS                                                               288607
                   FID        NDIR       NDIR       CHEMI       CHEMI           288607
                   UHC        CO         CO2        NO          NOX             288607
RANGE              1          1          2          3           3               288607
INSTR GAS TEMP     153.       51.        51.        60.         60.             288607
RAW VALUE MV         2.3      113.2      896.4      391.4       425.7           288607
GAS CONCEN PPM(C)    2.9        8.6       42412.6       96.3      104.8         288607
GAS CONCEN PCT     0.0003     0.0009     4.2413     0.0096      0.0105          288607
EMISSION INDEX     0.07       0.4        3157.         7.5         8.2          288607
FUEL-AIR RATIO     0.0208                                                       288607
```

```
                                                                                    287507
ENGINE TEST CATA                                                                    2875C7
CATE                          CATA PCINT            TEST CELL                       287507
C8/16/76                      287507                13                              287507
INSTRUMENT OPERATOR                                 TEST CPERATOR                   2875C7
ERHARCT                                             TREMBLEY                        287507
ENGINE MANUFACTURER           MCDEL                 SERIAL NUMBER                   287507
LYCCMING                      ALF-502               LF02                            2875C7
FUEL IDENT.                   FUEL FLCW PPH         MANIFCLC FUEL TEMP FAH          287507
JET-A HC RATIO C.161          1281.                 233.4                           287507
BELLMCUTH AIR FLCW LB/SEC     CORE AIRFLCW LB/SEC   FUEL-AIR RATIO MEAS.            287507
176.3                         25.3                  0.014C                          287507
PT3 PSIA                      TT3 DEG. RANKINE                                      287507
102.7                         1COC.5                                                2875C7
PT9 PSIA                      TT9 DEG RANKINE       EPR                             287507
16.198                        1341.5                 7.00                           287507
NET THRUST LBS                N1 RPM                N2 RPM                          287507
3227.0                        17178.                4752.                           2875C7
ACTUAL INLET PRESSURE PO PSIA                                                       287507
14.677                                                                              2875C7
ACTUAL INLET TEMPERATURE TO CEG. RANKINE                                            287507
522.7                                                                               2875C7
SPECIFIC HUMICITY GRAINS/LB CRY AIR                                                 2875C7
 61.2                                                                               2875C7
FILTER AREA .385 SI                                                                 287507
CLEAN CK SMOKE NUMBER 0                                                             287507
SMCKE NUMBEF        VOL.-LITERS     FLCW-CFM PRESS.-PSIA  TEMP. DEG.FAH             287507
        12.9                3.0         C.50      10.299            74.0            2875C7
        14.9                4.C         C.5C      10.299            74.C            287507
        22.4                7.0         0.50      10.299            74.0            287507
        29.2               11.0         C.50      1C.299            74.0            2875C7
GASECUS EMISSICNS                                                                   287507
                    FID         NDIR        NCIR        CHEMI       CHEMI           287507
                    UHC          CC          CO2         NO          NCX            2875C7
RANGE                1            1           2           2           2             287507
INSTR GAS TEMP      153.         52.         52.         60.         60.            287507
RAW VALUE MV          2.3       364.3       659.9       534.C       596.6           2875C7
GAS CCNCEN PPM(C)     2.4        31.9     29392.9        56.4        63.1           287507
GAS CCNCEN PCT      C.CCC2      0.CC32      2.9393      0.0056      0.C063          287507
EMISSION INDEX      0.C8          2.2      3154.          6.3         7.1           287507
FUEL-AIR PATIO      C.0144
```

```
ENGINE TEST DATA                                                              284407
DATE                      DATA POINT            TEST CELL                     284407
08/16/76                  284407                13                            284407
INSTRUMENT OPERATOR                             TEST OPERATOR                 284407
ERHARDT                                         TREMBLEY                      284407
ENGINE MANUFACTURER       MODEL                 SERIAL NUMBER                 284407
LYCOMING                  ALF-502               LF02                          284407
FUEL IDENT.               FUEL FLOW PPH         MANIFOLD FUEL TEMP FAH        284407
JET-A HC RATIO 0.161      1135.                 227.0                         284407
BELLMOUTH AIR FLOW LB/SEC CORE AIRFLOW LB/SEC   FUEL-AIR RATIO MEAS.          284407
164.8                     23.9                  0.0132                        284407
PT3 PSIA                  TT3 DEG. RANKINE                                    284407
 94.8                      976.2                                              284407
PT9 PSIA                  TT9 DEG RANKINE       EPR                           284407
15.999                    1303.0                 6.46                         284407
NET THRUST LBS            N1 RPM                N2 RPM                        284407
2819.0                    16802.                4435.                         284407
ACTUAL INLET PRESSURE PO PSIA                                                 284407
14.682                                                                        284407
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                                      284407
522.4                                                                         284407
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                           284407
 61.1                                                                         284407
FILTER AREA .385 SI                                                           284407
CLEAN CK SMOKE NUMBER 0                                                       284407
SMOKE NUMBER         VOL.-LITERS      FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH     284407
     10.9                    3.0          0.50    10.298             74.0     284407
     14.9                    4.0          0.50    10.298             74.0     284407
     18.7                    7.0          0.50    10.298             74.0     284407
     29.2                   11.0          0.50    10.298             74.0     284407
GASEOUS EMISSIONS                                                             284407
                     FID         NDIR        NDIR      CHEMI      CHEMI       284407
                     UHC         CO          CO2       NO          NOX        284407
RANGE                1           1           2         2           2          284407
INSTR GAS TEMP       154.        51.         51.       60.         60.        284407
RAW VALUE MV           2.7       532.0       620.6     467.2       537.9      284407
GAS CONCEN PPM(C)      2.7         49.6      27372.3      49.3        56.8    284407
GAS CONCEN PCT       0.0003      0.0050      2.7372    0.0049      0.0057     284407
EMISSION INDEX       0.10          3.6       3151.        5.9         6.8     284407
FUEL-AIR RATIO       0.0134                                                   284407
```

```
ENGINE TEST DATA                                                                    283307
DATE                          DATA POINT              TEST CELL                     283307
08/16/76                      283307                  13                            283307
INSTRUMENT OPERATOR                                   TEST OPERATOR                 283307
ERHARDT                                               TREMBLEY                      283307
ENGINE MANUFACTURER           MODEL                   SERIAL NUMBER                 283307
LYCOMING                      ALF-502                 LF02                          283307
FUEL IDENT.                   FUEL FLOW PPH           MANIFOLD FUEL TEMP FAH        283307
JET-A HC RATIO 0.161           778.                   214.9                         283307
BELLMOUTH AIR FLOW LB/SEC     CORE AIRFLOW LB/SEC     FUEL-AIR RATIO MEAS.          283307
134.3                         19.4                    0.0111                        283307
PT3 PSIA                      TT3 DEG. RANKINE                                      283307
 73.2                          905.2                                                283307
PT9 PSIA                      TT9 DEG RANKINE         EPR                           283307
15.503                        1203.0                   4.98                         283307
NET THRUST LBS                N1 RPM                  N2 RPM                        283307
1806.0                        15466.                  3619.                         283307
ACTUAL INLET PRESSURE PO PSIA                                                       283307
14.689                                                                              283307
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                                            283307
522.8                                                                               283307
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                                 283307
 62.5                                                                               283307
FILTER AREA .385 SI                                                                 283307
CLEAN CK SMOKE NUMBER 0                                                             283307
SMOKE NUMBER       VOL.-LITERS     FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH              283307
        4.5                3.0         0.50    10.299             73.0              283307
        8.8                4.0         0.50    10.299             73.0              283307
       10.9                7.0         0.50    10.299             73.0              283307
       16.8               11.0         0.48    10.299             73.0              283307
GASEOUS EMISSIONS                                                                   283307
                   FID        NDIR       NDIR       CHEMI      CHEMI                283307
                   UHC        CO         CO2        NO         NOX                  283307
RANGE              1          2          2          2          2                    283307
INSTR GAS TEMP     154.       56.        56.        60.        60.                  283307
RAW VALUE MV        13.4      301.1      530.9      298.9      379.8                283307
GAS CONCEN PPM(C)    11.0       123.6     22880.3       31.5       40.1             283307
GAS CONCEN PCT     0.0011     0.0124     2.2880     0.0032     0.0040               283307
EMISSION INDEX      0.48       10.8      3139.         4.5        5.8               283307
FUEL-AIR RATIO     0.0112                                                           283307
```

```
ENGINE TEST DATA                                                                   282207
DATE                        DATA POINT                 TEST CELL                   282207
08/16/76                    282207                     I3                          282207
INSTRUMENT OPERATOR                                    TEST OPERATOR               282207
ERHARDT                                                TREMBLEY                    282207
ENGINE MANUFACTURER         MODEL                      SERIAL NUMBER               282207
LYCOMING                    ALF-502                    LF02                        282207
FUEL IDENT.                 FUEL FLOW PPH              MANIFOLD FUEL TEMP FAH      282207
JET-A HC RATIO 0.161        442.                       170.0                       282207
BELLMOUTH AIR FLOW LB/SEC   CORE AIRFLOW LB/SEC        FUEL-AIR RATIO MEAS.        282207
 81.2                       11.4                       0.0108                      282207
PT3 PSIA                    TT3 DEG. RANKINE                                       282207
 39.9                        740.1                                                 282207
PT9 PSIA                    TT9 DEG RANKINE            EPR                         282207
14.986                      1215.5                      2.71                       282207
NET THRUST LBS              N1 RPM                     N2 RPM                      282207
 608.0                      12092.                     2157.                       282207
ACTUAL INLET PRESSURE PO PSIA                                                      282207
14.714                                                                             282207
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                                           282207
522.9                                                                              282207
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                                282207
 63.3                                                                              282207
FILTER AREA .385 SI                                                                282207
CLEAN CK SMOKE NUMBER 0                                                            282207
SMOKE NUMBER         VOL.-LITERS     FLOW-CFM  PRESS.-PSIA  TEMP. DEG.FAH          282207
         2.3                 3.0        0.48      10.298             72.0          282207
         2.3                 4.0        0.50      10.298             72.0          282207
         4.5                 7.0        0.50      10.298             72.0          282207
         6.7                11.0        0.50      10.298             72.0          282207
GASEOUS EMISSIONS                                                                  282207
                     FID         NDIR        NDIR        CHEMI       CHEMI         282207
                     UHC          CO          CO2         NO          NOX          282207
RANGE                 1           2           2           1           1            282207
INSTR GAS TEMP       154.        58.         58.         60.         60.           282207
RAW VALUE MV          94.4       785.9       523.9       554.8       974.2         282207
GAS CONCEN PPM(C)      73.4       385.6     22537.5        13.8        24.0        282207
GAS CONCEN PCT       0.0073      0.0386      2.2537      0.0014      0.0024        282207
EMISSION INDEX        3.19        33.7       3094.          2.0         3.4        282207
FUEL-AIR RATIO       0.0112                                                        282207
```

```
ENGINE TEST DATA                                                              281117
DATE                           DATA POINT          TEST CELL                  281117
08/16/76                       281117              13                         281117
INSTRUMENT OPERATOR                                TEST OPERATOR              281117
ERHARDT                                            TREMBLEY                   281117
ENGINE MANUFACTURER            MODEL               SERIAL NUMBER              281117
LYCOMING                       ALF-502             LF02                       281117
FUEL IDENT.                    FUEL FLOW PPH       MANIFOLD FUEL TEMP FAH     281117
JET-A HC RATIO 0.161            365.               158.4                      281117
BELLMOUTH AIR FLOW LB/SEC      CORE AIRFLOW LB/SEC FUEL-AIR RATIO MEAS.       281117
 65.8                           9.1                0.0112                     281117
PT3 PSIA                       TT3 DEG. RANKINE                               281117
 32.4                           690.6                                         281117
PT9 PSIA                       TT9 DEG RANKINE     EPR                        281117
14.888                         1240.6               2.20                      281117
NET THRUST LBS                 N1 RPM              N2 RPM                     281117
 391.0                         10552.              1771.                      281117
ACTUAL INLET PRESSURE PO PSIA                                                 281117
14.712                                                                        281117
ACTUAL INLET TEMPERATURE TO DEG. RANKINE                                      281117
523.0                                                                         281117
SPECIFIC HUMIDITY GRAINS/LB DRY AIR                                           281117
 63.3                                                                         281117
FILTER AREA .385 SI                                                           281117
CLEAN CK SMOKE NUMBER 0                                                       281117
SMOKE NUMBER      VOL.-LITERS    FLOW-CFM PRESS.-PSIA  TEMP. DEG.FAH          281117
         0.0              3.0        0.50    10.299            72.0           281117
         0.0              4.0        0.50    10.299            72.0           281117
         2.3              7.0        0.48    10.299            72.0           281117
         2.3             11.0        0.48    10.299            72.0           281117
GASEOUS EMISSIONS                                                             281117
                  FID        NDIR       NDIR        CHEMI      CHEMI          281117
                  UHC        CO         CO2         NO         NOX            281117
RANGE              2          2          2          1          1              281117
INSTR GAS TEMP    154.       58.        58.        60.        60.             281117
RAW VALUE MV       15.8      963.1      527.7      447.1      857.4           281117
GAS CONCEN PPM(C) 121.7       492.4      22669.2       11.3       21.4        281117
GAS CONCEN PCT    0.0122     0.0492     2.2669     0.0011     0.0021          281117
EMISSION INDEX      5.23      42.5      3074.         1.6        3.0          281117
FUEL-AIR RATIO    0.0113                                                      281117
```

B61/10

ENVIRONMENTAL PROTECTION AGENCY
Technical Publications Branch
Office of Administration
Research Triangle Park, North Carolina 27711

OFFICIAL BUSINESS
AN EQUAL OPPORTUNITY EMPLOYER

POSTAGE AND FEES PAID
ENVIRONMENTAL PROTECTION AGENCY
EPA - 335

SPECIAL FOURTH-CLASS RATE
BOOK

U.S. MAIL

Return this sheet if you do NOT wish to receive this material ☐ or if change of address is needed ☐ . (Indicate change, including ZIP code.)

PUBLICATION NO. EPA-460/3-77-017